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Naval Postgraduate School
Monterey, California 93943-5138

SUMMARY OF RESEARCH 1997

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13. ABSTRACT (Maximum 200 words.)

This report contains summaries of research projects in the Department of Physics. A list of recent publications is also included which consists of conference presentations and publications, books, contributions to books, published journal papers, technical reports, and thesis abstracts.

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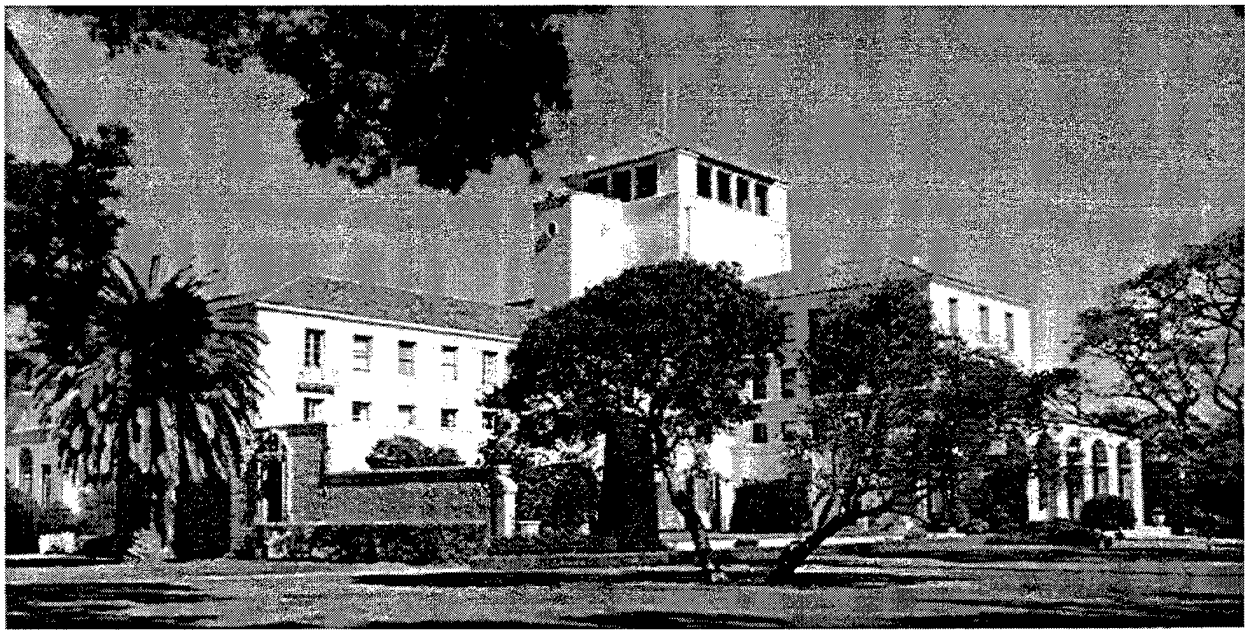
THE NAVAL POSTGRADUATE SCHOOL MISSION

The mission of the Naval Postgraduate School is to increase the combat effectiveness of U.S. and Allied armed forces and enhance the security of the USA through advanced education and research programs focused on the technical, analytical, and managerial tools needed to confront defense-related challenges



CONTENTS

PREFACE

Research at the Naval Postgraduate School is carried out by faculty in the School's eleven academic departments, four interdisciplinary groups, and the School of Aviation Safety. This volume contains research summaries for the projects undertaken by faculty in the Department of Physics during 1997. Also included is an overview of the department, faculty listing, a compilation of publications/presentations, and abstracts from theses directed by the department faculty.

Questions about particular projects may be directed to the faculty Principal Investigator listed, the Department Chair, or the Department Associate Chair for Research. Questions may also be directed to the Office of the Associate Provost and Dean of Research. General questions about the NPS Research Program should be directed to the Office of the Associate Provost and Dean of Research at (831) 656-2098 (voice) or research@nps.navy.mil (e-mail). Additional information is also available at the RESEARCH AT NPS website, http://web.nps.navy.mil~code09/.

INTRODUCTION

The research program at the Naval Postgraduate School exits to support the graduate education of our students. It does so by providing militarily relevant thesis topics that address issues from the current needs of the Fleet and Joint Forces to the science and technology that is required to sustain the long-term superiority of the Navy/DoD. It keeps our faculty current on Navy/DoD issues, permitting them to maintain the content of the upper division courses at the cutting edge of their disciplines. At the same time, the students and faculty together provide a very unique capability within the DoD for addressing warfighting problems. This capability is especially important at the present time when technology in general, and information operations in particular, are changing rapidly. Our officers must be able to think innovatively and have the knowledge and skills that will let them apply technologies that are being rapidly developed in both the commercial and military sectors. Their unique knowledge of the operational Navy, when combined with a challenging thesis project that requires them to apply their focussed graduate education, is one of the most effective methods for both solving Fleet problems and instilling the life-long capability for applying basic principles to the creative solution of complex problems.

The research program at NPS consists of both reimbursable (sponsored) and institutionally funded research. The research varies from very fundamental to very applied, from unclassified to all levels of classification.

- Reimbursable (Sponsored) Program: This program includes those projects externally funded on the basis of proposals submitted to outside sponsors by the School's faculty. These funds allow the faculty to interact closely with RDT&E program managers and high-level policymakers throughout the Navy, DoD, and other government agencies as well as with the private sector in defense-related technologies. The sponsored program utilizes Cooperative Research and Development Agreements (CRADAs) with private industry, participates in consortia with other government laboratories and universities, provides off-campus courses either on-site at the recipient command or by VTC, and provides short courses for technology updates.

- NPS Institutionally Funded Research Program (NIFR): The institutionally funded research program has several purposes: (1) to provide the initial support required for new faculty to establish a Navy/DoD relevant research area, (2) to provide support for major new initiatives that address near-term Fleet and OPNAV needs, (3) to enhance productive research that is reimbursable sponsored, (4) to contribute to the recapitalization of major scientific equipment, and (5) to cost-share the support of a strong post-doctoral program.

- Institute for Joint Warfare Analysis (IJWA) Program: The IJWA Program provides funding to stimulate innovative research ideas with a strong emphasis on joint, interdisciplinary areas. This funding ensures that joint relevance is a consideration of research faculty.

In 1997, the overall level of research effort at NPS was 151 faculty workyears and exceeded $32 million. The Department of Physics' effort was 10.59 faculty workyears and exceeded $1.8 million. The sponsored research program has grown steadily to provide the faculty and staff support that is required to sustain a strong and viable graduate school in times of reduced budgets. In FY97, over 87% percent of the NPS research program was externally supported. In the Department of Physics 83% was externally supported.

The department's research sponsorship in FY97 is provided in Figure 1.

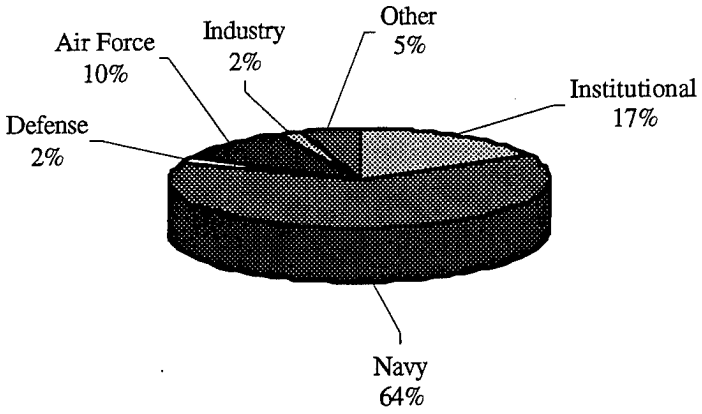


Figure 1. FY97 Sponsor Profile of the Department of Physics

These are both challenging and exciting times at NPS and the research program exists to help ensure that we remain unique in our ability to provide graduate education for the warfighter.

DAVID W. NETZER
Associate Provost and Dean of Research

January 1999

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DEPARTMENT SUMMARY

During CY 1997, 13 Physics Department faculty members participated in approximately 33 different research projects. Although the scope of these projects is quite broad, the research in the Physics Department can be grouped, for the purposes of this summary, into six general areas: (1) Electromagnetic Radiation and Propagation Phenomena; (2) Remote Sensing; (3) Weapons/Shipboard Systems Technologies; (4) Ocean Acoustics and Air/Sea Interactions; (5) Combat Systems Technology and Policy; and (6) Solid State Physics and Fundamental Processes. An overview of research activities in each of these areas follows.

Electromagnetic Radiation and Propagation Phenomena

Associate Professor Donald Walters continued work on atmospheric optical turbulence in support of the U.S. Air Force Airborne Laser Program. He served as the Air Force's technical representative on a number of occasions. In addition, ten years of atmospheric coherence length and isoplanatic angle measurements were collated and compared. This study showed how solar illumination introduced a factor of ten errors in daytime balloon measurements, and how the problem could be eliminated. Understanding the atmospheric turbulence parameters is a key part determining the viability of optical communication systems for multi Giga bit communication links. To this end Professor Walters initiated a project to evaluate and assess large weather models such as the COAMPS and MM5 Mesoscale Weather models to predict atmospheric turbulence and cloud formation. He is comparing post-processed model results with existing atmospheric optical data and to assessing the desirability and direction for further work.

Associate Professor Scott Davis continued a multi-year project, which has as its primary goal the development of a proof-of-concept prototype instrument capable of recording fully multiplexed images and multispectral images at long infrared wavelengths, where efficient focal plane array technology is not available. The task completed during this research was the design of the prototype opto-mechanical and opto-electronic servo system which will be responsible for spatial positioning of the instrument's Walsh encoding masks to very fine (micron-tolerance) precision.

Professor William Colson continued work in the area of free electron laser (FEL) simulations. His areas of interest include simulation of new and existing FELs for ship self-defense, and FEL simulation for industry partners. His involvement included investigation of wavelength modulation and limit cycle behavior in FELs, atmospheric propagation simulations of high average power FEL, and ultraviolet FELs.

Professor Alf Cooper continued work in a number of areas related to the application of infrared technology to the Navy in support of Naval Sea Systems Command and Space and Naval Warfare Systems Center-San Diego. One project involves the development of a split-field Long Wave Infra Red (LWIR) polarimeter. Another involves analysis of IR ship signatures from the PREOS92 experiment.

Remote Sensing

Associate Professors David Cleary and Chris Olsen continued work in the area of hyperspectral remote sensing. Professor Cleary is conducting experimental work in this field. He has completed the construction of an ultraviolet hyperspectral imager and a hyperspectral polarimeter. Initial testing of these devices has begun and will continue in 1998. Professor Olsen is working on the phenomenology and algorithm development of hyperspectral imaging. His concentration is on littoral and near-shore environments.

Associate Professor Robert Harney developed laser and lidar technologies. During 1996 a laser/lidar laboratory was established. During 1997 the assembly of a breadboard, cw Doppler lidar (including laser, detector, acousto-optic modulator, optics, and radio frequency electronics) was completed. The performance of this lidar in detecting vibrations was verified in the laboratory using a special calibration source assembled during 1996 under this task. Conceptual design of wavelength-tunable and ultraviolet laser sources as upgrades to this aerosol-profiling lidar was also conducted.

Weapons/Shipboard Systems Technologies

Associate Professor Thomas Hofler worked in the area of thermoacoustics. Thermoacoustics is an emerging technology that represents a feasible, non-CFC, non-global warmer cooling alternative. Previously, a laboratory prototype cooling engine of a new design was modeled numerically, partially optimized, and constructed. The prototype has produced much data in 1997 on a variety of thermoacoustic stacks and resonator tuning combinations. Audible noise from the engine is

significant at about 70 dBA. Recently, the analysis and design of the engine has been modified to achieve vibration cancellation. The hope is for a noise reduction of 20 dB or more when the new modifications are tested.

Associate Professor Harney worked to integrate the electromagnetic engineering (EMENG) suite of tools and top-side design principles being developed by the Combat Systems Design and Engineering Group (03K) of NAVSEA into NPS Total Ship Systems Engineering (TSSE) program. The intent is to educate the TSSE students concerning the need and techniques for improving the electromagnetic characteristics and performance of a surface combatant, and to serve as a beta test site for proving out the evolving EMENG suite of computer-aided design tools. During 1997 the new Windows NT-compatible version of the EMENG suite of computer-aided design and analysis tools was obtained from NAVSEA. Necessary additional database, X-windows, Fortran compiler, and C++ compiler software were purchased. The NAVSEA-provided Intergraph computer hardware and personal computers running Windows NT have been incorporated into the TSSE laboratory area.

Ocean Acoustics and Air/Sea Interactions

Assistant Professor Kevin Smith worked on several projects concerning ocean acoustic propagation. High quality acoustic reverberation data were collected during the Acoustic Reverberation Special Research Program's (ARSRP) main acoustics cruise in the summer of 1993. The ability to correlate these measured returns with bathymetric features depends on the signal resolution. A study of the effects of multipath propagation on signal resolution was proposed. Analysis of the measured data provided a means of confirming predictions of these effects. An advanced PE propagation model was used to quantify these effects in the ARSRP environment. This research is a continuation of a FY96 research project sponsored by ONR. During FY97, a direct comparison between a simpler continuous wave (CW) approach and an advanced broadband calculation was made to determine the exact influence of such multipath propagation. It was determined that in isolated regions these secondary multipaths can influence the reverberation by as much as 20 dB, but that over most ranges of interest, the simple CW approach works extremely well.

The objective of another project was to study the physics and predictability of 3-D, broadband acoustic propagation upslope onto the continental shelf in the presence of strong oceanographic frontal features, specifically in the vicinity of the mid-Atlantic Bight. Finally, he was involved with a study of the influence of the physics mismatch due to less-than-ideal acoustic ray model predictions on the localization of full-wave signals and to coordinate future research efforts towards a system demonstration of passive transient localization.

Research Associate Professor Donald Spiel is continuing a research project involved in determining the ocean's aerosol source function. That is, to determine how many aerosols per unit time per unit area are generated by oceanic processes. In the past year, the effort to determine the birth of jet drops over the range of bubble sizes 350 to 1500 μm radius was completed. The ejection speeds, time of ejection, and the height at which all the jet droplets broke off the ascending jet were measured. Previously, the size distributions of these drops were determined. In addition, a theoretical solution to the problem of the number of film drops as a function of bubble size was advanced. Experiments were begun to test the efficacy of this theory. Work on the ejection parameters of jet drops for the bubble size range 0.5 to 3 mm-diameter was completed during 1997. During this year, a hypothesis was advanced to explain the peak in film drop production in the bubble size range 2 to 2.5 mm-diameter was advanced. Measurements of film drop production and theoretical calculations have led to a broad understanding on film drop production.

Combat Systems Technology and Policy

Professor Xavier Maruyama participated in activities associated with the Institute for Joint Warfare Analysis. The project investigated available and potential technologies related to Technologies for Operations Other than War (TOOTW), including Less-than-Lethal Weapons, Landmines, Defensive Technologies, Situational Awareness Technologies, and Training and Simulation Issues.

Solid State Physics and Fundamental Processes

Associate Professor James Luscombe is involved with a project to advance the state of the art in quantum device modeling. He is developing a wide variety of models for electrons in semiconductor nanostructures and associated issues related to the

ultimate scaling of electronic devices. In addition, he is developing models of the self-consistent electrostatic potential in quantum dot nanostructures as well as solutions to the Schrödinger equation in quantum wire geometries. He is also working to develop models of the time-dependent, nonequilibrium elastic scattering structure factor for the investigation of strongly nonequilibrium processes in adsorbed surface overlayers.

There were two separate thrusts to his research this year: (1) He examined theoretically the effects of deliberate compositional modifications to semiconductor superlattices on electron dynamics. He then used the insights gained to develop a proposal for a spatially selective photo-excitation process that would reduce the dephasing of Bloch oscillation signals, and hence lead to significantly longer-lived Bloch oscillations. Bloch oscillations in semiconductor superlattices are a possible means of generating TeraHertz electromagnetic radiation. (2) He developed models of the magnetic properties of recently synthesized molecular clusters containing a relatively small number (4-10) of magnetic atoms. He developed a classical spin model to predict the magnetic susceptibility and compared it with recent experimental data. The insights gained from this theory were used to develop a model of the nuclear-magnetic-resonance (NMR) spin-lattice relaxation time in small magnetic clusters. Magnetic molecular clusters have possible applications as ultra-dense information storage systems.

Assistant Professor Andrés Larraza is establishing basic experimental and theoretical research in nonlinear waves. Two areas of research were covered: absorption of sound by noise with possible applications to the excess attenuation in a shallow water environment and basic experimental and theoretical research on acoustic analogs to effects predicted from the properties of the electromagnetic zero point field (ZPF). This new area of research has the potential to test a broad array of new concepts where the ZPF may play a major role, including inertia, gravitation and sonoluminescence. The use of broadband noise in the acoustic analog to the Casimir effect may lead to non-resonant acoustic levitation and manipulation.

The Department of Physics maintains and a linear electron accelerator (linac) and a flash x-ray machine. The facilities are used for classroom and research use especially by the Departments of Physics and Electrical and Computer Engineering. The principal investigator for these facilities is Professor Xavier Maruyama. He collaborated on a research project that studied the radiation effects on electronics and investigation of parametric x-radiation.

NUMERICAL MODELING OF SONAR TRANSDUCERS AND ARRAYS

Steven R. Baker, Associate Professor
Department of Physics
Clyde Scandrett, Associate Professor
Department of Mathematics
Sponsor: Office Naval Research

OBJECTIVE: Support is sought for three tasks: (1) to conduct a survey of available numerical structural/acoustic computer codes, (2) to tabulate the capabilities of each in the key areas pertinent to sonar transducers and array modeling, and (3) to continue development of the T-matrix method for the performance modeling of arbitrarily densely- and randomly-packed sonar arrays. Specifically, it is proposed to continue to investigate codes to computer acoustic scattering, with particular attention to the nearfield, and host a sonar transducer and array modeling workshop at the Naval Postgraduate School.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Active Sonar, Transducer, Array, Modeling, Finite-Element

ANALYSIS OF VIBRATION MEASUREMENTS IN SUPPORT OF THE ELECTRO-OPTICAL SENSOR UPGRADE TO THE PHALANX CLOSE-IN WEAPON SYSTEM

Steven R. Baker, Associate Professor
Department of Physics
Sponsor: Naval Surface Warfare Center-Dahlgren Division

OBJECTIVE: To continue analysis of vibration measurements made in FY96 on a prototype of the new Phalanx electro-optical sensor package during a live-fire exercise. In particular, to analyze the rotation of the FLIR camera mount and the plane of the stabilizer pedestal feet.

DoD KEY TECHNOLOGY AREA: Conventional Weapons

KEYWORDS: Phalanx CIWS, Structural Vibration, Vibration

AN INVESTIGATION OF THE USE OF POLARIZATION WITH THE HYDICE HYPERSPECTRAL IMAGER

David D. Cleary, Associate Professor
Department of Physics
Sponsor: Navy Tactical Exploitation of National Capabilities Office and Naval Postgraduate School

OBJECTIVE: The objective of this project was to investigate the use of multispectral and hyperspectral polarization for automatic target recognition in satellite imaging systems. This is a new concept whereby the Stokes polarization parameters would be measured for every band of a multispectral imager or for every channel of a hyperspectral imager. Measurement of these parameters could greatly improve our automatic target recognition capabilities in support of military operations. While this technique adds a fourth dimension to the traditional 3-D data cube, it could actually lower the bandwidth requirements of existing and future imaging systems.

SUMMARY: Unlike "traditional" polarimetry, which typically involves panchromatic measurements of the angular dependent BRDF, focus was on the spectral dependence of polarization. The polarization signature was measured of 15 different materials of military interest. In general, hyperspectral polarization signature is positive and anti-correlated with reflectance. Degree-of-polarization increases with increasing angle-of-reflectance. Dark targets exhibit a larger degree-of-

polarization than reflectance. Specular targets exhibit negative polarization. Distinctive polarization features are apparent for unpainted aluminum and synthetic fiber targets.

THESIS DIRECTED:

Rigo, M., "The Use of Polarization with Hyperspectral Imaging," Master's Thesis, Naval Postgraduate School, December 1997.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Hyperspectral Imaging

ULTRAVIOLET HYPERSPECTRAL IMAGING

David D. Cleary, Associate Professor
Department of Physics
Sponsor: United States Air Force

OBJECTIVE: The objective of this project is to measure the ultraviolet spectra of a variety of materials and gases of military interest to determine the existence of any significant spectroscopic signature. The overall goal is to assess whether there is added value in extending the spectral coverage of hyperspectral imagers to include the near ultraviolet (300 to 400 nm).

SUMMARY: To date, the UV spectra of over 15 materials commonly included in hyperspectral measurement studies have been measured. Based on these measurements, it is concluded that the UV signatures of these materials are not sufficiently unique to warrant a significant push toward shorter wavelengths. The use of ultraviolet remote sensing for the detection of gases, however, does show great promise. Sulfur dioxide has been chosen as an initial demonstration of this technique. SO2 concentrations have been measured as low as 10 ppm-m and as high as 1500 ppm-m. Preparations are currently being made to make field measurements of the Pu'u O'o volcano in Hawaii.

THESIS DIRECTED:

Hooks, T.A., "Development and Testing of the NPS Ultraviolet Imaging Spectrograph (NUVIS)," Master's Thesis, Naval Postgraduate School, December 1997.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Hyperspectral Imaging

A NOVEL TECHNIQUE FOR SEARCH AND GEOLOCATION OF SIGNALS FROM LOW-EARTH ORBIT

David D. Cleary, Associate Professor
Department, of Physics
Sponsor: United States Navy

OBJECTIVE: The objective is to investigate new techniques for search and geolocation using receiver systems that have both wide field-of-view and high gain.

SUMMARY: An imaging system was designed that can operate at radar frequencies and has in principle both wide field-of-view and high gain. This system makes use of a technique known as multiplexed imaging. The concept of operations

(CONOPS) under which this device would be used was developed. Currently, the expected performance of this device is being analyzed including the estimated sources of system noise.

OTHER:

A Multiplexed Imaging System for Microwave Frequencies, Navy Case No. 78779 (patent filed).

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Hyperspectral Imaging

FREE ELECTRON LASER FOR SHIP DEFENSE

William B. Colson, Professor
Department of Physics
Sponsor: Naval Postgraduate School

OBJECTIVE: The research is proposed for the study of the high-average-power infrared wavelength free electron laser developed by the Navy's Directed Energy Office at the Jefferson National Laboratory (formerly CEBAF), Newport News, VA.

SUMMARY: The Navy's Directed Energy Office is developing a high-power UV free electron laser for industrial processing. NPS has used numerical simulations to help guide the design and development. The design also meets many of the requirements for a high-power shipboard laser weapon. The Navy's Directed Energy Office's proposed design is powered by a super-conducting RF accelerator that would produce 100 kW of laser power at UV wavelengths and would cost about $30 M.

PUBLICATIONS:

Colson, W.B., "Short Wavelength Free Electron Lasers in 1996," *Nuclear Instruments and Methods in Physics Research A393*, 6, 1997.

Colson, W.B., "Theory of High Gain Free Electron Lasers," *Nuclear Instruments and Methods in Physics Research A393*, 82, 1997.

CONFERENCE PRESENTATION:

Colson, W.B., "The World's First X-Ray Laser," Physics Department Colloquium, Naval Postgraduate School, Monterey, CA, July 1997.

THESIS DIRECTED:

Small, D.W., "Interaction of Laser Beams With Relativistic Electrons," Doctor of Philosophy Dissertation, Naval Postgraduate School, March 1997.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Manufacturing Science and Technology

KEYWORDS: Free Electron Laser, Industrial Laser Processing

NORTHROP/GRUMMAN FREE ELECTRON LASER RESEARCH

William B. Colson, Professor
Department of Physics
Sponsor: Northrop/Grumman Advanced Technology and Development Center, Bethpage, NY

OBJECTIVE: Northrop/Grumman is interested in developing the free electron laser technology for industrial and military applications requiring high average power.

SUMMARY: Northrop/Grumman has developed a low power free electron laser (FEL) for scientific use in the far infrared wavelength range. They are developing the accelerator and FEL technology that applies to high average power capable of defending Navy ships against sea-skimming cruise missiles. Simulations describe the performance of an FEL capable of damaging cruise missiles at a range of about 10 km. The power requirements that must be provided by the ship are studied. NPS and Northrop/Grumman have collaborated on the requirements for shipboard deployment of a 1 MW FEL. Research studied the packaging of the Northrop/Grumman FEL technology for Navy ship defense and to compare Northrop/Grumman and NPS FEL simulations.

PUBLICATION:

Todd, A.M.M., Colson, W.B., and Neil, G.R., "Megawatt-Class Free Electron Laser Concept for Shipboard Self-Defense," *SPIE* A2988, 176, 1997.

CONFERENCE PRESENTATION:

Todd, A.M.M., Colson, W.B., and Neil, G.R., "Megawatt-Class Free Electron Laser Concept for Shipboard Self-Defense," SPIE LASER '97, San Jose, CA, February1997.

THESIS DIRECTED:

Restivo, R.A., "Free Electron Laser Weapons and Electron Beam Transport," Master's Thesis, Naval Postgraduate School, June 1997.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Directed Energy Weapons

KEYWORDS: Free Electron Laser, High Energy Laser

HIGH POWER INFRARED FREE ELECTRON LASERS FOR SHIP DEFENSE

William B. Colson, Professor
Department of Physics
Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: The research studies high average power infrared wavelength free electron lasers (FELs) at the Thomas Jefferson National Accelerator Facility (formerly the Continuous Electron Beam Accelerator Facility), Newport News, VA. SPAWAR is developing the technology for using FELs to defend ships against sea-skimming missiles.

SUMMARY: NPS is working with the Jefferson National Laboratory (formerly CEBAF) and SPAWAR to develop the superconducting accelerator technology to power a 1 MW FEL for ship defense. The design must meet the requirements for a high-power shipboard laser weapon.

PUBLICATIONS:

Anderson, E. and Colson, W.B., "Ship Design Optimization for a CEBAF Free Electron Laser," *Nuclear Instruments and Methods in Physics Research*, A393, II-149, 1997.

Small, D.W., Wong, R.K., Colson, W.B., and Armstead, R.L., "Free Electron Lasers with Short Rayleigh Length," *Nuclear Instruments and Methods in Physics Research*, A393, 262, 1997.

CONFERENCE PRESENTATIONS:

Kesselring, M., Colson, W.B., Wong, R.K., and Sheffield, R., "Simulations of the LANL Regenerative Amplifier FEL," poster paper at the Nineteenth International Free Electron Laser Conference, Beijing, China, August 1997.

Nguyen, R.T., Colson, W.B., Wong, R.K., and Sheffield, R., "Simulation of a Regenerative MW FEL Amplifier," poster paper at the Nineteenth International Free Electron Laser Conference, Beijing, China, August 1997.

THESES DIRECTED:

Kesselring, M.D., "Simulations of the LANL 1 kW Regenerative Amplifier FEL," Master's Thesis, Naval Postgraduate School, September 1997.

Nguyen, R.T., "Simulations of the LANL 1 kW Regenerative MW Free Electron Laser Amplifier," Master's Thesis, Naval Postgraduate School, March 1997.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Directed Energy Weapons

KEYWORDS: Free Electron Laser, High Energy Laser

REMOTE SENSING - POLARIZATION EFFECTS IN THE INFRARED

Alfred W. M. Cooper, Professor
Department of Physics
Sponsors: Space and Naval Warfare Systems Center-San Diego

OBJECTIVE: To develop instrumentation and techniques for measurement of environmental factors needed for prediction, analysis, and modeling of infrared sensor performance in the marine boundary layer. This includes target and background signatures, polarization, and sun glint, and local atmospheric profiles.

SUMMARY: Previous measurements have shown that polarization filtering can improve target/background contrast in infrared imaging. The NPS Split Field Polarimeter and internally mounted polarizers were used in the EOPACE measurement series (San Diego, November 1996) to record an extensive database of sea, shore, and ship imagery with vertical and horizontal polarizations. Laboratory calibration characteristics were determined for the split-field images for the new Cedip 12 bit data acquisition software, for comparison with in-scene reference sources. A simple polarization-dependent quantitative range prediction model has been developed to evaluate polarization influence on target detection range. The image database was catalogued and image sets selected for further quantitative analysis. The polarimeter has been adapted for use with a 10X large aperture telescope for resolution of 0.1 mrad.

DoD KEY TECHNOLOGY AREAS: Sensors, Battlespace Environments, Electronic Warfare.

KEYWORDS: Atmospheric Optics, Infrared Sensors, IRST

SHIP SIGNATURES AND TARGET DETECTION—DETECTION AND RECOGNITION CRITERIA IN FLIR TDA

Alfred W. M. Cooper, Professor
Department of Physics
Sponsors: Space and Naval Warfare Systems Center-San Diego

OBJECTIVE: To improve the prediction of detection range for infrared signatures through evaluation of environmentally modified ship signatures and experimental evaluation of criteria for detection and recognition.

SUMMARY: Physical and meteorological parameters selected from the database of the EOMET95 Monterey Bay measurements with the research vessel *Point Sur* were used to define a consistent set of conditions for evaluation of range dependent Apparent Contrast Temperature Difference for the ship against the sea background. Maximum detection and recognition ranges were evaluated by comparison of the apparent temperature difference with the required Minimum Detectable and Minimum Resolvable Temperature Difference Modeled (MRTD). Atmospheric correction of contrast using the SEARAD version of MODTRAN was compared with the commonly used Beer's Law form based on an average extinction coefficient. MRTD and MDTD for a generic Common Module FLIR were modeled as functions of range using the Johnson Criterion for detection and a simple ship model. A mounting for insertion of the polarizing beam-splitter coated for the 3-5 micrometer (MWIR) band into the split-field polarimeter has been constructed and a bench setup completed for incorporation of the polarimeter with the large telescope for increasing resolution to 0.1 milliradians. Selection of EOPACE image data for evaluation of detection ranges was initiated but delayed pending correction of instrument-related calibration problems. Processing programs for automatic selection and averaging of target image pixels and background have been written and application begun.

THESIS DIRECTED:

Yu, C.-L., "Estimate of Maximum Detection Range for FLIR from EOMET95 Measurement Data," Master's Thesis, Naval Postgraduate School, December 1997.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Modeling and Simulation

KEYWORDS: Atmospheric Optics, Infrared Sensors, FLIR.

INFRARED SURVEILLANCE AND TARGET DISCRIMINATION RESEARCH

Alfred W. M. Cooper, Professor
Department of Physics
Sponsor: Naval Postgraduate School

OBJECTIVES: The objectives are: (1) to investigate the influence of atmospheric refraction and turbulence on the detection and location of small near-horizon targets by infrared imaging systems (particularly Thermal Imaging Systems including Infrared Search and Track Systems and FLIR) operating in the marine surface layer and (2) to compare the results with model predictions using LOWTRAN, MODTRAN, and IRTOOL. This is a continuing project.

SUMMARY: A large aperture telescope was modified to operate in conjunction with an AMBER infrared focal plane camera to provide resolution at 0.1 mrad at f/# of 1.8, suitable for measurement of atmospheric refraction and turbulent spread on sea-grazing paths of order 20 km. This will allow measurement in Monterey Bay when the necessary cooperative support measures are available. The IRTOOL system performance simulation code has been installed and operated to predict detection range and apparent target location for an initial set of scenarios based on estimated current generation IRST parameters with low-flying small targets.

DoD KEY TECHNOLOGY AREAS: Sensors, Battlespace Environments, Electronic Warfare

KEYWORDS: Atmospheric Optics, Infrared Sensors, IRST

DESIGN-DEVELOPMENT OF CONTROL SYSTEM FOR MULTIPLEXED KRONECKER PRODUCT IMAGER

D. Scott Davis, Associate Professor
Department of Physics
Sponsor: Naval Postgraduate School

OBJECTIVE: To design a prototype servo control system for precise mask positioning in the Kronecker product multiplexed imager.

SUMMARY: The next-generation medium and far infrared multiplexed imaging system will be based upon the Kronecker product approach invented at the Naval Postgraduate School (D.S. Davis: "Multiplexed Imaging by Means of Optically-generated Kronecker Products: 1. The Basic Concept," *Applied Optics*, pp. 1170 – 1176, 1995). The task completed during this research was the design of the prototype opto-mechanical and opto-electronic servo system which will be responsible for spatial positioning of the instrument's Walsh encoding masks to very fine (micron-tolerance) precision.

PUBLICATION:

Davis, D.S., "Design for a Fully-Multiplexed Imaging Fourier Transform Spectrometer," *Proceedings of the Optical Society of America Technical Digest Series,* pp. 32-34, 1997.

Davis, D.S. "A Fully-Multiplexed Imaging Fourier Transform Spectrometer," *Proceedings of the Optical Society of America Winter Topical Conference,* January 1997.

DoD KEY TECHNOLOGY AREAS: Sensors

KEYWORDS: Infrared, Multiplexing, Imaging, Spectroscopy

COMBAT SYSTEM ELECTROMAGNETIC ENGINEERING

Robert C. Harney, Associate Professor
Department of Physics
Sponsor: Naval Sea Systems Command

OBJECTIVE: The objective of this project is to integrate the electromagnetic engineering (EMENG) suite of tools and top-side design principles being developed by the Combat Systems Design and Engineering Group (03K) of NAVSEA into NPS's Total Ship Systems Engineering (TSSE) program. The intent is to educate the TSSE students concerning the need and techniques for improving the electromagnetic characteristics and performance of a surface combatant and to serve as a beta test site for proving out the evolving EMENG suite of computer-aided design tools.

SUMMARY: During 1997 the new Windows NT-compatible version of the EMENG suite of computer-aided design and analysis tools was obtained from NAVSEA. Necessary additional database, X-windows, Fortran compiler, and C++ compiler software was purchased. The NAVSEA-provided Intergraph computer hardware and personal computers running Windows NT have been incorporated into the TSSE laboratory area. A subcontract was placed with Systems Integration and Research, Inc., to provide continuing applications support through June 1998 via the involvement of Frank Fassnacht (the original principal investigator). The process of extracting the minimum required data from the software manuals and condensing it into a form simplified for student assimilation was begun and will continue into early 1998. After generating a simplified user manual, several test cases will be developed for incorporation into the TSSE 4000 (Combat Systems

Integration) course as student laboratory exercises and into the TS4002/ TS4003 (Capstone Ship Design Project) courses as design tools. The laboratory exercises will demonstrate to the students the use of each of the key functional aspects of the EMENG software suite that they will need to use in the Capstone Ship Design Project.

DoD KEY TECHNOLOGY AREA: Other (Design Automation)

KEYWORDS: Topside Design, Electromagnetic Interference, Electromagnetic Engineering, Computer-Aided Design, Total Ship Systems Engineering, Combat System Engineering

INVESTIGATION OF HARD KILL-SOFT KILL INTERACTIONS

Robert C. Harney, Associate Professor
Department of Physics
D. Curtis Schleher, Professor
Information Warfare Academic Group
Sponsor: Naval Sea Systems Command

OBJECTIVE: The objective of this project is to investigate the interactions of soft-kill weapons (jammers, decoys, etc.) with hard-kill weapons (guns, interceptor missiles, etc.) in an air defense environment. This project will identify and catalog all potential interaction of each soft-kill system with each hard-kill system (and vice versa), so that the information can be properly incorporated into self-defense systems.

SUMMARY: Existing and advanced developmental hard-kill and soft-kill systems have been identified as have the most serious missile threats. Each system has been evaluated for any effect it may have on any other of the identified systems. A considerable number of potentially serious interactions have now been identified. For example, chaff is a useful decoy against some active radar missile seekers. However, after chaff is deployed, it will reflect signals from many radars. Missile seeker radar signals will be reflected into electronic support (ES) receivers producing false missile targets in the ES system. This may potentially degrade the performance of jammers or the performance of semiactive guided interceptors by misdirecting the jamming or illuminator beams (which are pointed by the ES system). Tracking radar signals reflected from the chaff may degrade the tracking performance of those radars. The interactions identified in this work can have significant impacts on the utilization of defensive assets. For example, the chaff-radar interaction may further limit the choice of locations relative to the ship for chaff employment (they are already limited by decoy effectiveness), and it may require inputting the selected location into the ES system processor (so that "targets" in that direction are ignored). These interactions and their potential effects have been catalogued and are being documented in the final report. In potential follow-ons to this work it is hoped to quantify the magnitudes of effects resulting from the identified interactions, to thereby determine which interactions are significant and which may be effectively ignored, and to devise strategies for optimizing the performance of the combined defensive systems.

DoD KEY TECHNOLOGY AREA: Electronic Warfare

KEYWORDS: Electronic Combat, Countermeasures, Air Defense Weapons, Hard Kill, Soft Kill

DEVELOPMENT OF LASER AND LIDAR TECHNOLOGIES

Robert C. Harney, Associate Professor
Department of Physics
Sponsor: Naval Postgraduate School

OBJECTIVE: The objective of this project is to establish a laboratory suitable for the development of novel laser sources for lidar (laser radar) systems and studying the applications of laser and lidar technologies to military problems. Specific objectives include demonstration of a simple cw Doppler lidar for remote sensing of vibrations suitable for measurements in support of concept development and subsequent proposals, assembly of a backscatter lidar that can be used for aerosol

profiling, and development of novel laser sources for upgrading these lidars as well as incorporation into new lidar applications.

SUMMARY: During 1997 the assembly of a breadboard, cw Doppler lidar (including laser, detector, acousto-optic modulator, optics, and rf electronics) was completed. The performance of this lidar in detecting vibrations was verified in the laboratory using a special calibration source assembled during 1996 under this task. The design, assembly, and performance verification was documented in a thesis published in March 1997 by CPT Jim Day. CPT Day's data was obtained using an analog spectrum analyzer borrowed from another researcher. Processing of the data was limited to those modes implemented in the hardware. Data archival was limited to a paper printout. To facilitate more extensive digital signal processing as well as digital data storage for archival purposes and to create a system independent of borrowed equipment, a personal computer-based digital data acquisition and processing system was procured. This system was integrated with the lidar hardware and work on programming a virtual spectrum analyzer into the computer using the LabView software system was begun. This work is being performed by LCDR Felix Montez and will be documented in his thesis to be finished in June 1998.

Follow-on efforts to this work are expected to be funded by other sources and are strongly dependent on student interest and participation. Most probable will be the repackaging of the breadboard optical system into a more compact and rugged design suitable for field measurements. All components anticipated for this activity are now on hand. A third student has indicated tentative interest but has not yet submitted a formal thesis proposal.

In addition to the Doppler lidar efforts described above, further equipment was procured to facilitate development of other laser and lidar projects. A high-prf green laser, narrowband filters, and scanning optics have been procured for an aerosol backscatter lidar. Flashlamps and optical mounts have been procured to facilitate development of a tunable laser source for a differential absorption lidar.

DoD KEY TECHNOLOGY AREA: Electronic Warfare

KEYWORDS: LIDAR, Remote Sensing

IMPROVED EFFICIENCY AND POWER DENSITY FOR THERMOACOUSTIC COOLERS

Thomas J. Hofler, Associate Professor
Department of Physics
Sponsors: Office of Naval Research and Naval Postgraduate School

OBJECTIVE: To perform basic research on thermoacoustic cooling processes for applications requiring high cooling power and a small temperature span. The specific focus is on a heat driven cooling engine with no moving parts. This system could use a waste heat source such as the gas turbine exhaust on a Navy surface vessel.

SUMMARY: Previously, a laboratory prototype cooling engine of a new design was modeled numerically, partially optimized, and constructed. The prototype has produced much data in 1997 on a variety of thermoacoustic stacks and resonator tuning combinations.

The numerical model predicts stability/onset criteria for acoustic oscillations that are very sensitive to the temperature distribution of the resonator. This has been borne out experimentally and is utilized to thermally tune the engine to facilitate start-up, without adding moving parts. Thermal tuning is a big advantage of the current design, eliminating the need for excessively high temperatures.

A variety of new stack structures have been successfully tested in the engine. Stacks made from randomly oriented stainless steel wire mesh, random porous carbon foam, and rolled stainless steel foil, have produced good performance, with varying characteristics.

The design model predicted performance numbers of 500 W of cooling power at a temperature span of 40° C, for 1160 W of heat input, yielding an overall coefficient-of-performance of COP = 43%. In June, the engine first produced good refrigeration, and the best performance numbers are as follows: A maximum refrigerated temperature span of 65° C; and a maximum cooling power of 91W at a span of 25° C, for a COP of 15%.

In short, the performance shows good temperature span, with significant but modest power and efficiency. The power level is commensurate with the acoustic amplitude which is half of the anticipated design value. It is also known that the heat exchangers are limiting both power and efficiency, and the stacks are perhaps limiting efficiency. Also, the operation of the engine appears to be very simple, stable, and free from any known reliability problems. Audible noise from the engine is significant at about 70 dBA. Recently, the analysis and design of the engine has been modified to achieve vibration cancellation. The hope is for a noise reduction of 20 dB or more, when the new modifications are tested.

PUBLICATIONS:

Adeff, J.A., Hofler, T.J., Atchley, A.A., and Moss, W.C., "Measurements with Reticulated Vitreous Carbon Stacks in Thermoacoustic Prime Movers and Refrigerators," *Journal of the Acoustical Society of America*, accepted for publication.

Hofler, T.J. and Adeff, J.A., "Improvements in an Experimental Thermoacoustically Driven Thermoacoustic Refrigerator," *Journal of the Acoustical Society of America*, Vol. 102, No. 5, Pt. 2, p. 3071, San Diego, CA, November 1997.

Hofler, T.J., Adeff, J.A., and Atchley, A.A., "Experimental Results with a Thermoacoustically Driven Thermoacoustic Refrigerator," *Journal of the Acoustical Society of America,* Vol. 101, No. 5 Pt. 2, p. 3021, State College, PA, June 1997.

CONFERENCE PRESENTATIONS:

Hofler, T.J. and Adeff, J.A., "Improvements in an Experimental Thermoacoustically Driven Thermoacoustic Refrigerator," Acoustical Society of America, San Diego, CA, November 1997.

Hofler, T.J., Adeff, J.A., and Atchley, A.A., "Experimental Results with a Thermoacoustically Driven Thermoacoustic Refrigerator," Acoustical Society of America, State College, PA, June 1997.

DoD KEY TECHNOLOGY AREA: Other (Energy Conversion)

KEYWORDS: Thermoacoustic, Refrigeration, Cooler

ACOUSTIC ANALOGS TO ELECTROMAGNETIC ZERO POINT FIELD EFFECTS

Andrés Larraza, Assistant Professor
Department of Physics
Sponsor: Naval Postgraduate School

OBJECTIVE: To establish basic experimental and theoretical research on acoustic analogs to effects predicted from the properties of the electromagnetic zero point field (ZPF). This new area of research has the potential to test a broad array of new concepts where the ZPF may play a major role, including inertia, gravitation, and sonoluminescence. The use of broadband noise in the acoustic analog to the Casimir effect may lead to non–resonant acoustic levitation and manipulation.

SUMMARY: Theoretical and experimental results were obtained for the force law between two rigid, parallel plates due to the radiation pressure of broadband acoustic noise. The noise is in the band of 5 to 15 kHz and has an intensity of 133 dB (re 10^{-12} W/m^2). Excellent agreement is shown between theory and experiment. These results constitute an acoustic analog for the Casimir effect, which is the force experienced by two closely spaced uncharged conducting plates due to the quantum electromagnetic zero point field. In contrast to this case, however, band limited noise can cause the force to be *attractive* or *repulsive* as a function of separation between the plates. Applications of the acoustic Casimir effect to noise transduction can provide new means to measure background noise. Because attractive or repulsive forces can be obtained by adjusting the noise spectrum or the plate geometry, a non-resonant method of acoustic levitation can also be possible.

PUBLICATIONS:

Larraza, A., Holmes, C.D., Susbilla, R.T., and Denardo, B., "The Force of Attraction Between Two Parallel Rigid Plates due to the Radiation Pressure of Broadband Noise: An Acoustic Casimir Effect," accepted for publication in the *Journal of the Acoustical of Society of America.*

Larraza, A. and Denardo, B., "An Acoustic Casimir Effect," submitted.

CONFERENCE PRESENTATIONS:

Larraza, A., "Some Acoustic Analogs to Electromagnetic Zero Point Field Effects: Static and Dynamic Acoustic Casimir Effects," *Quantum Aspects of Beam Physics*, Monterey, CA, January 1998.

Simmons, T., Denardo, B., Larraza, A., and Keolian, R., "An Acoustic Radiometer," Acoustical Society of America Meeting, June 1998.

Larraza, A., Holmes, C.D., Susbilla, R.T., and Denardo, B., "An Acoustic Casimir Effect, Acoustical Society of America Meeting, June 1998.

Larraza, A., "An Acoustic Casimir Effect," Department of Physics Colloquium, Naval Postgraduate School, 15 August 1997.

THESIS DIRECTED:

Holmes, C.D., "Acoustic Casimir Effect," Master's Thesis, Naval Postgraduate School, June 1997.

DoD KEY TECHNOLOGY AREA: Other (Environmental Effects)

KEYWORDS: Electromagnetic Zero Point Field, Random Waves, Linear Acoustics

INVESTIGATIONS OF NONLINEAR ACOUSTIC NOISE

Andrés Larraza, Assistant Professor
Department of Physics
Sponsor: University of Mississippi

OBJECTIVE: To perform experimental and numerical investigations of the effect on a signal due to interactions with intense noise. Both, the effect of reducing the bandwidth of the noise while keeping the noise intensity constant and the effect of band-limited periodic noise will be investigated. Further properties of the nonlinear noise, including downstream injection of the signal and the possibility of collective modes, will also be investigated numerically.

SUMMARY: Nonlinear noise can probe the nature of systems driven far off equilibrium. This was established by measurements that probe the Gaussian nature of the absorption of sound by noise in one dimension and by observations of the power law spectrum of fully developed shockless noise. The Gaussian attenuation of a monochromatic signal in the presence of discrete noise in one dimension has been numerically verified. Two new results have also been uncovered. In the first, a transition was observed from Gaussian to Bessel dependence as a function of resolution in the detection of a signal. This result shows that the fundamental property of time reversibility can only be established if the overall system of the waves and the observer is considered. In the second result, the evolution was investigated of the amplitude of a signal injected downstream from the noise. Again the Gaussian attenuation was observed. This result explicitly shows that the attenuation length depends on the distance the signal has traveled, thus displaying memory and breakdown of translational invariance. Additionally, numerical and analytical searches for collective modes are currently being performed for shockless and shock noise, respectively. Although such modes in far off equilibrium noise have been predicted in several systems, there are

currently no controlled observations. These modes are important, for example, as a mechanism of energy transfer. If this behavior is numerically or analytically indicated for one-dimensional acoustics, it will be experimentally established. Besides probing a variety of fundamental issues, our nonlinear noise research may have applications to noise generation and control, especially in regard to supersonic vehicles. An understanding may lead to techniques to actively suppress the development of shocks.

PUBLICATIONS:

Larraza, A. and Denardo, B., "Acoustic Waveguides as Tools in Fundamental Nonlinear Physics," eds: Phillip F. Schewe and Ben P. Stein, *Physics News in 1996,* pp. 2-3, American Institute of Physics, College Park, MD, 1997.

Larraza, A. and Denardo, B., "Acoustic Waveguides as Tools in Fundamental Nonlinear Physics," *Journal of the Acoustical Society of America,* 101 1997.

Mital, V., Denardo, B., Jang, H., and Larraza, A., "Numerical Simulations of the Absorption of Sound by Noise in One Dimension," *Journal of the Acoustical Society of America*, 101, No. 5, Pt. 2, 3080, 1997.

CONFERENCE PRESENTATION:

Mital, V., Denardo, B., Jang, H., and Larraza, A., "Numerical Simulations of the Absorption of Sound by Noise in One Dimension," Acoustical Society of America, State College, PA, 1997.

THESES DIRECTED:

Lamczyk, M. and Park, J., "Experimental and Theoretical Investigations of the Gaussian Suppression of Sound by Sound," Master's Thesis, Naval Postgraduate School, June 1997.

Mital, V., "Numerical Simulations of the Absorption of Sound by Noise in One Dimension," Master's Thesis, University of Mississippi, August 1997.

DoD KEY TECHNOLOGY AREA: Other (Environmental Effects)

KEYWORDS: Nonlinear Waves, Random Waves.

DEVELOPMENT OF QUANTUM DEVICE MODELS

James H. Luscombe, Associate Professor
Department of Physics
Sponsor: Naval Postgraduate School

OBJECTIVE: The goal of this program is to develop theoretical models of the electronic, magnetic, and structural properties of materials and systems at the nanometer length scale. While the primary emphasis is on developing models of heterostructure quantum electron devices, there is also interest in nano-scale magnetic systems. This is a continuing project.

SUMMARY: There were two separate thrusts to the research this year: (1) To examine theoretically the effects of deliberate compositional modifications to semiconductor superlattices on electron dynamics. The insights gained were then used to develop a proposal for a spatially selective photo-excitation process that would reduce the dephasing of Bloch oscillation signals, and hence lead to significantly longer-lived Bloch oscillations. Bloch oscillations in semiconductor superlattices are a possible means of generating TeraHertz electromagnetic radiation. (2) Models were developed of the magnetic properties of recently synthesized molecular clusters containing a relatively small number (4-10) of magnetic atoms. A classical spin model was developed to predict the magnetic susceptibility and compared with recent experimental data. The insights gained from this theory were used to develop a model of the nuclear-magnetic-resonance (NMR) spin-lattice

relaxation time in small magnetic clusters. Magnetic molecular clusters have possible applications as ultra-dense information storage systems.

PUBLICATIONS:

Borsa, F., Jang, Z., Shastri, A., Luban, M., Lascialfari, A., Gatteschi, D. and Luscombe, J.H., "Proton Spin-Lattice Relaxation and Spin Dynamics in Magnetic Molecular Clusters," *Bulletin of the American Physical Society*, Vol. 42, p. 731, 1997.

Luban, M. and Luscombe, J.H., "Dynamical Localization of Electrons in Aperiodic Superlattices," *Physical Review B*, accepted for publication.

Luban, M., Reynolds, J.P., and Luscombe, J.H., "Enhanced Lifetimes of Bloch Oscillations by Spatially Selective Photoexcitation," *Proceedings of the International Semiconductor Device Research Symposium*, Vol. 4, p. 533-537, 1997.

Luscombe, J.H. and Luban, M., "Wave-Vector-Dependent Magnetic Susceptibility of Classical Heisenberg Rings," *Journal of Physics: Condensed Matter*, Vol. 9, p. 6913-20, 1997.

Luscombe, J.H. and Luban, M., "Classical Heisenberg Model of Magnetic Molecular Ring Clusters: Accurate Approximates for Correlation Functions and Susceptibility," *Journal of Chemical Physics*, accepted for publication.

Luscombe, J.H., Luban, M., and Borsa, F., "Classical Heisenberg Model of a Ring Nanostructure: Correlation Functions and Susceptibility," *Bulletin of the American Physical Society*, Vol. 42, p. 258, 1997.

Reynolds, J.P., Luban, M., and Luscombe, J.H., "Long-Lived Quasi-Periodic Bloch Oscillations by Spatially Selective Photoexcitation," *Bulletin of the American Physical Society*, Vol. 42, p. 607, 1997.

CONFERENCE PRESENTATIONS:

Borsa, F., Jang, Z., Shastri, A., Luban, M., Lascialfari, A., Gatteschi, D., and Luscombe, J.H., "Proton Spin-Lattice Relaxation and Spin Dynamics in Magnetic Molecular Clusters," Meeting of the American Physical Society, Kansas City, MO, 17-21 March 1997.

Luban, M., Jang, Z., and Luscombe, J.H., "Proton Spin-Lattice Relaxation Rate for Magnetic Molecular Ring Clusters," Meeting of the American Physical Society, Los Angeles, CA, 16-20 March 1997.

Luban, M., Reynolds, J.P., and Luscombe, J.H., "Enhanced Lifetimes of Bloch Oscillations by Spatially Selective Photoexcitation," International Semiconductor Device Research Symposium, Charlottesville, VA, 11-13 December 1997.

Luscombe, J.H., Luban, M., and Borsa, F., "Classical Heisenberg Model of a Ring Nanostructure: Correlation Functions and Susceptibility," Meeting of the American Physical Society, Kansas City, MO, 17-21 March 1997.

Luscombe, J.H., "Nano-Scale Electronics for the 21st Century," Innovation and Defense Technology 2020, Pacific Grove, CA, 1-4 December 1997.

Luscombe, J.H., Luban, M., and Reynolds, J.P., "Variational Tight-Binding Theory of Excitons in Compositionally Modified Semiconductor Superlattices," Meeting of the American Physical Society, Los Angeles, CA, 16-20 March 1998.

Reynolds, J.P., Luban, M., and Luscombe, J.H., "Long-Lived Quasi-Periodic Bloch Oscillations by Spatially Selective Photoexcitation," Meeting of the American Physical Society, Kansas City, MO, 17-21 March 1997.

THESES DIRECTED:

Johnson, B., "Numerical Acceleration of the Mie Scattering Series," Master's Thesis, Naval Postgraduate School, December 1997.

Kruppa, S., "Modeling Quantum-Dot Devices," Master's Thesis, Naval Postgraduate School, June 1997.

Spencer, F., "High-Precision Computational Method for the Quantum Transmission Coefficient," Master's Thesis, Naval Postgraduate School, December 1997.

DoD KEY TECHNOLOGY AREAS: Electronics, Materials, Processes and Structures, Modeling and Simulation

KEYWORDS: Nanoelectronics, Nanotechnology, Nanomagnetism

TESTING AND CHARACTERIZATION OF A ONE-METER ELECTROMAGNETIC RAILGUN

William B. Maier, Senior Lecturer
Department of Physics
Sponsor: Naval Postgraduate School

OBJECTIVE: The purpose of this research is to discover the operating parameters, e.g., current pulse shape, that maximize the efficiency with which energy is transferred to the railgun projectile. The information would be used to optimize railgun operation.

SUMMARY: Railgun theory and practice have been reexamined to determine the best current shape for the current pulse driving a railgun projectile. The approach to this problem has been primarily theoretical. The capacitors for the one-meter railgun failed early in the year, so the experiment was transferred to a smaller device. At the same time, the effect of current pulse shape on projectile velocity was studied theoretically. The results show that the dependence on current pulse shape depends in turn on the mechanisms by which energy is dissipated in the system.

DoD KEY TECHNOLOGY AREA: Conventional Weapons

KEYWORDS: Electromagnetic Railgun, Projectile Velocities

THESIS DIRECTED:

Hartke, J.P., "Characterization and Magnetic Augmentation of a Low Voltage Electromagnetic Railgun," Master's Thesis, Naval Postgraduate School, December 1997.

RADIATION SOURCES AT THE NAVAL POSTGRADUATE SCHOOL

Xavier K. Maruyama, Professor
Department of Physics
Sponsor: Naval Postgraduate School

OBJECTIVE: The radiation sources at NPS, the 100 MeV RF electron linear accelerator and the 1.7 MV pulsed flash x-ray machine, are required for a number of projects at NPS including the study of unipolar arcing plasma physics, investigation of novel sources of coherent radiation and radiation effects in materials and electronic devices. In addition, there are radioactive sources, which are primarily used for detector calibration and for classroom laboratories and demonstration. These are available to a variety of investigators from the Naval Postgraduate School and their associated external collabo-

rators. In addition to the use as radiation sources, the facility capabilities are maintained to provide NPS with resources for pulsed power technology.

SUMMARY: The works cited here arise from activities of this present year and from past years. Experiments leading to publication in high-energy physics is not currently being pursued, but the product of previous years endeavors are continuing. Contributions were made to the E143 collaboration at SLAC which is an important effort to understand the underlying quark structure of nucleons and within nuclei.

Study of photon generation mechanisms to produce x-rays for application such as photolithography. Transition and parametric radiation investigation continue. In addition, x-ray optics was investigated using polycapillary lenses.

Collaborative efforts with students in a nuclear physics laboratory course led to a here-to-for uninvestigated study of the radioactive glaze in collectible chinaware. This study is truly multidisciplinary in that radiation physics, Manhattan Project era political history and knowledge of American antiques and collectibles were necessary to create a method to differentiate pre- and post- World War II American chinaware.

Because the radiation sources can be viewed as a school resource, not all work associated with this effort are reported here. In particular, Associate Professor Sheriff Michael of the Department of Electrical and Computer Engineering, conducted experiments with thesis students in radiation effects on fault tolerant circuits and CPT John Hartke, USA, did his thesis work concerning railgun technology using the resources of the radiation facilities.

PUBLICATIONS:

Abe, K., Akagi, T., Anthony, P.L., Antonov, R., Arnold, R.G., Averett, T., Band, H.R., Bauer, J.M., Borel, H., Bosted, P.E., Breton, V., Button-Shafer, J., Chen, J.P., Chupp, T.E., Cledenin, J., Comptour, C., Coulter, K.P., Court, G., Crabb, D., Daoudi, M., Day, D., Dietrich, F.S., Day, D., Dietrich, F.S., Dunne, J., Dutz, H., Erbacher, R., Fellbaum, J., Feltham, A., Fonvieille, H., Friez, E., Garvey, D., Gearhart, R., Gomez, J., Grenier, P., Griffioen, K.A., Hoibraten, S., Hughes, E.W., Hyde-Wright, C., Johnson, J.R., Kawall, D., Klein, A., Kuhn, S.E., Kuriki, M., Lindgren, R., Liu, T.J., Lombard-Nelsen, R.M., Marroncle, J., Maruyama, X.K. McCarthy, J., Meyer, W., Meziani, Z.E., Minehart, R., Mitchell, J., Morgenstern, J., Petratos, G.C., Pitthan, R., Pocanic, D., Prescott, C., Prepost, R., Raines, P., Raue, B., Reyna, D., Rijllart, A., Roblin, Y., Rochester, L., Rock, S.E., Rondon, O.A., Sick, I., Smith, L.C., Smith, T.B., Spengos, M., Staley, F., Steiner, P., St. Lorant S., Stuart, L.M., Suekane, F., Szalata, Z.M., Tang, H., Terrien, Y., Usher, T., Walz, D., White, J.LK., Witte, K., Young, C., Youngman, B., Yuta, H., Zapalac, G., Zihlmann, B., Zimmerman, D., (The E143 Collaboration), "Measurement of the Proton and Deuteron Spin Structure Function g1 in the Resonance Region," *Physical Review Letters* 78, 815, 1997.

Piestrup, M.A., Powell, M.W., Mrowka, S., Lombardo, L.W., Chase, M.B., Cremer, J.T. and Maruyama, X.K., "A Single-Stepper Soft-X-Ray Source for Step-and-Scan Tools," *SPIE*, Vol. 3048, pp.176-182, 1997.

Piestrup, M.A., Powell, W.W., Mrowka, S., Cremer, J.T., Lombardo, L.W., Chase, M.B., Snyder, D., Rietdyk, H., and Maruyama, X.K., "A Transition Radiation Source with a Grazing Angle Optic for Step and Scan Lithography," *Proceedings of the International Symposium on Radiation of Relativistic Electrons in Periodical Structures*, RREPS-97, Tomsk, Russia, September 1997.

Schagin, A.V. and Maruyama, X.K., "Parametric X Rays," Chapter 9, *Accelerator-Based Atomic Physics Techniques and Applications,* pp. 279-307, Stephen M. Shafroth and James C. Austin (eds), American Institute of Physics, 1997.

CONFERENCE PRESENTATIONS:

Alba, A., Hartke, J., Chase, M., Hooks, T.A., Rietdyk, H., Snyder, D., Maruyama, X.K., "Effect of Nuclear Weapons on Red China," Joint Southern California and Northern California/Nevada Spring 1997 Meeting, American Association of Physics Teachers, Cal Poly, San Luis Obispo, CA, 25-26 April 1997.

Piestrup, M.A., Powell, W.W., Mrowka, S., Cremer, J.T., Lombardo, L.W., Chase, M.B., Snyder, D., Rietdyk, H., and Maruyama, X.K., "A Transition Radiation Source with a Grazing Angle Optic for Step and Scan Lithography," Interna-

tional Symposium on Radiation of Relativistic Electrons in Periodical Structures, RREPS-97, Tomsk, Russia, September 1997.

Piestrup, M.A., Powell, M.W., Mrowka, S., Lombardo, L.W., Chase, M.B., Cremer, J.T., Maruyama, X.K., "A Single-Stepper Soft-X-Ray Source for Step-and-Scan Tools," SPIE, San Francisco, CA, March 1997.

THESIS DIRECTED:

Chase, M.B., "Boro-Silicate Polycapillary Lens for Collimation of X-Rays," Master's Thesis, Naval Postgraduate School, June 1997.

OTHER:

Maruyama, X.K., "The Effect of Nuclear Weapons on Red China or How the Manhattan Project Changed the Red Glaze on Ceramics," Department of Physics, Naval Postgraduate School, Monterey, CA, 16 May 1997, colloquium.

DoD KEY TECHNOLOGY AREA: Other (Radiation)

KEYWORDS: Accelerator, Klystron, Linac, Flash X-Ray, Radiation, Parametric X-Ray, Railgun, Radiation Effects

TECHNOLOGIES FOR OPERATIONS OTHER THAN WAR

Xavier K. Maruyama, Professor
Department of Physics
Sponsor: Naval Postgraduate School-Institute of Joint Warfare Analysis

OBJECTIVE: This project is to investigate the technological innovation and their implications for Military Operations Other Than War (MOOTW). In particular, non-lethal weaponry, mine detection, demining, sniper and anti-sniper technologies, vehicle add on armor and individual soldier communications are technologies which are necessary for major regional conflicts, but have implications in MOOTW.

SUMMARY: Assessment of technologies applicable to MOOTW has been conducted. In addition, the relationship between these technologies and other civil-military areas of concern, such as aviation security, weapons of mass destruction and terrorism have been explored. By their nature, MOOTW requires interservice and multilateral cooperation. This program allows for participation in mine detection and clearance efforts.

This program initiated involvement in aviation security and local emergency response activities. The involvement in aviation security has led to a separate FAA sponsored project discussed below. The local emergency response involvement has led to a separate activity concerning response to chem-bio terrorism events.

PUBLICATION:

Maruyama, X.K., Cochran, T.B., Norris, R.S., and Bukharin, O.A., "Making the Russian Bomb, From Stalin to Yeltsin," book review for *Naval War College Review*, p. 159, Winter 1997, Vol. L, No. 1, Sequence 357.

OTHER:

Shaw, A., Fainberg, T., and Maruyama, X.K., "Technologies for Peace Support Operations," Congressional Research Service Seminar, Library of Congress, Washington DC, 8 January 1997.

THESIS DIRECTED:

Leonardy, T., "Implementation and Evaluation of an INS System for the Shepherd Rotary Vehicle," Master's Thesis, Naval Postgraduate School, December 1997.

DoD KEY TECHNOLOGY AREA: Other (Non-Lethal Weapons)

KEYWORDS: MOOTW, WMD

BIOLOGICAL AND CHEMICAL TERRORISM AND ASSESSMENT, LOCAL AND NATIONAL RESPONSE COORDINATION

Xavier K. Maruyama, Professor
Department of Physics
Sponsor: Naval Postgraduate School-Institute of Joint Warfare Analysis

OBJECTIVE: The purpose of this program is to increase our understanding of and improve our response mechanisms in the event of biological or chemical terrorism. The immediate response will depend on the ability of local emergency agencies to cope with the act. Consequently, it is critical to understand local emergency response mechanisms. A computer model will be created with input data taken from actual events and/or drill exercises.

SUMMARY: This work studied the local emergency response mechanism. A major multi-casualty incident, MCI, drill was conducted on 22 November 1997 in which over 170 people participated including, 60 victims, 10 fire trucks, 4 ambulances, a helicopter and 30 data collectors in addition to other personnel. Our role was to take data during a multi-casualty incident in order to quantify the local emergency response mechanism. This data will be incorporated into models to investigate the role of local emergency response units in a chem-bio WMD terrorism incident. A report concerning the 22 November 1997 Pacific Grove, CA, MCI drill will be issued in winter 1998 as an Institute for Joint Warfare Analysis report. This work is partially the results of earlier efforts in studying MOOTW.

DoD KEY TECHNOLOGY AREA: Other (Terrorism)

KEYWORDS: Biological or Chemical Terrorism, MOOTW

AVIATION SAFETY/ SECURITY TECHNOLOGY ASSESSMENT

Xavier K. Maruyama, Professor
Department of Physics
Sponsors: Federal Aviation Agency and
Naval Postgraduate School-Institute of Joint Warfare Analysis

OBJECTIVE: The White House Commission on Aviation and Security has recommended the deployment of existing technology and establishment of research and development programs to enhance the security of air travel. This proposal is to assess technologies relating to explosive detection in cargo, checked baggage, carry-on bags, and passengers, in a language which airline executives and day-to-day operators can understand. The final report will enable the airline operators to understand the scientific and engineering basis for the various technologies so that they may better evaluate the strengths and weaknesses of existing and developing technologies.

SUMMARY: The project is in the exploratory stage. The subject matter for this project is intimately related to the previous projects, concerning military operations other than war (MOOTW) and response to terrorism. Preliminary work related to this project was begun under the auspices of the Institute of Joint Warfare Analysis.

DoD KEY TECHNOLOGY AREA: Other (Security)

KEYWORDS: MOOTW, Air Travel, Terrorism

OPERATIONAL FEASIBILITY OF RIGID FOAM AS A MINE COUNTERMEASURE

Xavier K. Maruyama, Professor
Department of Physics
Sponsor: Office of Naval Research

OBJECTIVE: To determine the operational feasibility of the use of rigid foam for countermine use. Rigid foam has been shown in the laboratory to be feasible for absorbing mine blast and for distributing weight sufficiently to allow vehicles and personnel to transit over explosives. The research will address technical and operational issues on the use of rigid foam. A technical curriculum army student has committed to work on this thesis arena. If this effort has support, at least one other student will be recruited, preferably from the Special Operations Arena to look at scenario driven operational issues.

SUMMARY: Experiments were conducted at Waterways Experimental Station, Vicksburg, MS, and Energetic Materials Research and Testing Center, Soccoro, NM, to investigate the feasibility of using rigid polyurethane foam (RPF), for operational countermine use. RPF can withstand the explosive effects of anti-personnel blast mines and mitigate or neutralize the effects of surface laid anti-vehicular mines. This work was done as part of a larger effort conducted by Sandia National Laboratories. Results will be presented in the 1998 Mine Technology Symposium, Monterey, CA, April 1998.

THESIS DIRECTED:

Alba, A.L., "Rigid Polyurethane Foam as a Breaching Technique for Anti-Personnel Mines," Master's Thesis, Naval Postgraduate School, December 1997.

DoD KEY TECHNOLOGY AREA: Other (Mine Warfare)

KEYWORDS: Mine Countermeasures

LIQUID METAL ION GUN FLIGHT EXPERIMENT

Richard C. Olsen, Associate Professor
Department of Physics
Sponsor: National Aeronautics and Space Administration-Goddard Space Flight Center

OBJECTIVE: Prepare charge control experiment for launch on the European Space Agency (ESA) Cluster satellite mission. NPS responsibilities are to procure tile substrate and support charging analysis.

SUMMARY: The project had a small setback when the Ariane V launch vehicle blew up in February 1996. ESA initiated a recovery effort involving utilization of the flight spare instruments for a near-term flight, and construction of four replacement satellites. Fresh tile materials were provided for the construction of a new instrument.

DoD KEY TECHNOLOGY AREA: Space Vehicles

KEYWORDS: Spacecraft Charging, Ion Beams, Spacecraft-Environment Interactions

APPLICATION OF HYPERSPECTRAL IMAGING TO NAVAL APPLICATIONS

Richard C. Olsen, Associate Professor
Department of Physics
Sponsor: Naval Research Laboratory

OBJECTIVE: To address the application of multispectral and hyperspectral imaging to naval needs and to participate in activities utilizing HYDICE and other instruments, and analyze data collected during these experiments.

SUMMARY: Hyperspectral image data have been acquired from experimental sensors and are being analyzed using non-literal techniques. The objectives are to identify target signatures and other features of interest in land and littoral scenes. Data from HYMSMO projects have been analyzed. Students participated in data collections with HYDICE and other systems.

PUBLICATIONS:

Collins, B.H., Olsen, R.C., and Hackwell, J., "Thermal Imagery Spectral Analysis," *Proceedings of Imaging Spectrometry III, SPIE*, Vol., 3118, pp. 94-105, 1997.

Olsen, R.C., Bergman, S., and Resmini, R.C., "Target Detection in a Forest Environment Using Spectral Imagery," *Proceedings of Imaging Spectrometry III, SPIE,* Vol. 3118, pp. 46-56, 1997.

CONFERENCE PRESENTATIONS:

Collins, B.H., Olsen, R.C., and Hackwell, J., "Thermal Imagery Spectral Analysis," Imaging Spectrometry III, SPIE Annual Meeting, San Diego, CA, 28-30 July 1997.

Olsen, R., Bergman, C.S., and Resmini, R.C., "Target Detection in a Forest Environment Using Spectral Imagery," SPIE Annual Meeting, San Diego, CA, 28-30 July 1997.

THESIS DIRECTED:

Stefanou, M.S., "A Signal Processing Perspective of Hyperspectral Imagery Analysis Techniques," Master's Thesis, Naval Postgraduate School, June 1997.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Remote Sensing, Targeting, Trafficability

INFRARED SUBMARINE STUDIES

Richard C. Olsen, Associate Professor
Department of Physics
Sponsor: Naval Engineering Logistics Office

OBJECTIVE: Study the infrared measurements of submarines.

SUMMARY: Data from national systems were analyzed. Results are being transferred to operational intelligence commands.

THESIS DIRECTED:

Deans, K., "Thermal Imagery of Submarines," Master's Thesis, Naval Postgraduate School, September 1997.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Remote Sensing, National Systems, ASW, TENCAP

POLAR SATELLITE FLIGHT EXPERIMENT

Richard C. Olsen, Associate Professor
Department of Physics
Sponsor: National Aeronautics and Space Administration-Marshall Space Flight Center

OBJECTIVE: To analyze data taken during charge control experiments on the NASA POLAR satellite mission.

SUMMARY: The POLAR satellite was launched on 24 February 1996. The Plasma Source Instrument (PSI) was successfully operated for the first time on 15 April 1996. After a decade of effort, the plasma source performed as intended, grounding the satellite frame to the ambient plasma potential. This allowed highly sensitive measurements of the ambient plasma characteristics to be made. Data from all the 1996 and early 1997 experiments were analyzed in a special class offering of a class in spacecraft-environment interactions.

DoD KEY TECHNOLOGY AREA: Space Vehicles

KEYWORDS: Spacecraft Charging, Spacecraft-Environment Interactions

VOLCANIC ASH DRIFT

Richard C. Olsen, Associate Professor
Department of Physics
Sponsors: U.S. Geological Survey and Naval Postgraduate School

OBJECTIVE: The proposal is to enhance model based ash drift forecasts using near real time observations. Products derived from classified and unclassified systems will be used to provide model input. Campaign strategies will be developed for acquisition of necessary "ground truth" information.

SUMMARY: Volcanic ash clouds are a hazard for civil and military aircraft. The ability to identify the boundaries of hazardous regions requires both observations and models of ash cloud behavior. In the first year of study, data from the AVHRR sensor was analyzed. AVHRR data were acquired for volcanic events on the Kamchatka peninsula. Software was developed for the analysis of such data, in order to distinguish between ash and water clouds. These data were compared with observations from national systems, which showed agreement at some times, but "false alarms" at others. The Cobra Brass sensor launched in late 1997 will provide a complementary data set which should enable real-time warnings and model input. Analysis of Cobra Brass data will begin in 1998.

DoD KEY TECHNOLOGY AREAS: Sensors, Battlespace Environment

KEYWORDS: Remote Sensing, Environmental Monitoring

COOPERATIVE DEVELOPMENT OF HUMANITARIAN ASSISTANCE/DISASTER RELIEF OPERATIONS HA/DR

Gordon Schacher, Professor
Department of Physics
Sponsor: Trippler Army Medical Center

OBJECTIVE: The modeling and simulation of HA/DR response and mitigation is not yet well developed and is closely related to chemical/biology incident mitigation modeling. A program of providing the operational research foundation, developing models and engaging in the education/training in Humanitarian Assistance/Disaster Relief (HA/DR) is proposed. The Naval Postgraduate School will provide operations research courses for CEDMHA/PACOM personnel, do research into understanding of the HA/DR activities and consult with CEDMHA in the development of requirements for models to support the CEDMHA mission. Where appropriate NPS will develop models and train personnel in their use and interpretation. NPS will conduct workshops and conferences of experts in modeling to ensure a broad review of the requirements and models.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Humanitarian Assistance, Disaster Relief

BOTTOM REVERBERATION DATA ANALYSIS AND PROPAGATION MODELING OF COMPLEX MULTIPATHS

Kevin B. Smith, Assistant Professor
Department of Physics
Sponsor: Office of Naval Research and Naval Postgraduate School

OBJECTIVE: The scientific objective of this work is to understand the limits of signal resolution imposed by complex forward-propagating multipaths. This will be studied in both deep and shallow water environments with data from the 1993 Acoustic Reverberation Special Research Program (ARSRP) acoustics cruise used to compare deep-water results. Proposed here is a two-year program involving data analysis, model predictions, and the software development to support and improve both.

SUMMARY: High quality acoustic reverberation data was collected during ARSRP's main acoustics cruise in the summer of 1993. The ability to correlate these measured returns with bathymetric features depends on the signal resolution. A study of the effects of multipath propagation on signal resolution is proposed. Analysis of the measured data will provide a means of confirming predictions of these effects. An advanced PE propagation model will be used to quantify these effects in the ARSRP environment. This research is a continuation of a FY96 research project sponsored by Office of Naval Research (ONR). During FY97, a direct comparison between a simpler, CW approach and an advanced, broadband calculation was made to determine the exact influence of such multipath propagation. It was determined that in isolated regions these secondary multipaths can influence the reverberation by as much as 20 dB, but that over most ranges of interest, the simple CW approach works extremely well.

PUBLICATION:

Smith, K.B. and Cushman, E.B., "A Comparison of Quasi-Continuous Wave and Broadband Travel Time Techniques in the Prediction of Long-Range Reverberation," *Journal of the Acoustical Society of America*, 102, pp. 2063- 2071, 1997.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Other (Environmental Effects, Acoustic Reverberation, Sonar Performance)

KEYWORDS: Acoustic Reverberation, Propagation, Multipaths

AN EXAMINATION OF 3D, BROADBAND ACOUSTIC PROPAGATION PHYSICS IN A LITTORAL OCEAN ENVIRONMENT - AN EXTENSION TO AN ONR PRIMER FIELD STUDY IN THE MID-ATLANTIC BIGHT

Kevin B. Smith, Assistant Professor
Department of Physics
Sponsor: Office of Naval Research

OBJECTIVE: The scientific objective of this work is to study the physics and predictability of 3-D, broadband acoustic propagation upslope onto the continental shelf in the presence of strong oceanographic frontal features, specifically in the vicinity of the mid-Atlantic Bight.

SUMMARY: With the emphasis of undersea warfare (USW) shifting to littoral environments, the understanding and, ultimately, prediction of acoustic propagation in the vicinity of the shelfbreak becomes increasingly important. The sloping bathymetry, the extreme seasonal changes in the vertical sound-speed structure and the significant horizontal variability generated by the shelfbreak front are just a few of the environmental factors that make this problem both interesting and complex. Under the PRIMER initiative, the Office of Naval Research is sponsoring a multi-year study of acoustic propagation in the region of the North Atlantic Bight off the coast of New Jersey. This region is of interest due to the combination of sloping bathymetry near the continental shelf and the strong oceanographic frontal features associated with the Gulf Stream. The general purpose of this project is to study the effects of the frontal region on acoustic propagation onto the shelf. This research is a complementary study of propagation effects and data analysis. Specifically, the influence of three-dimensional propagation effects and their influence on the prediction of broadband measurements in similar oceanographic regions shall be addressed. In addition to the experimental components already in place, the deployment of explosive SUS charges were coordinated throughout the area at the beginning and end of the study. The addition of these very broadband sources will provide valuable information on specific frequency dependent phenomena. A major effort this year has been the development of direct techniques to extract information on geo-acoustic parameters from the broadband SUS data and the ambient noise field. Additionally, analysis of the data from moored sources has provided detailed information about plane wave variability due to propagation through this complicated region. Both large-scale water mass motion and tidal influences on the front produce observable effects on the received data.

PUBLICATIONS:

Chiu, C.-S., Smith, K.B., Lynch, J.F., Gawarkiewicz, G.G., Pickart, R.S., Sperry, B., Miller, J.H., and Robinson, A.R., "Measurement and Analysis of the Propagation of Sound from the Continental Slope to the Continental Shelf," *Journal of the Acoustical Society of America*, Vol. 102, p. 3143, 1997.

Gawarkiewicz, G.G., Pickart, R.S., Lynch, J.F., Chiu, C.-S., Smith, K.B., and Miller, J.H., "The Shelfbreak Front PRIMER Experiment," *Journal of the Acoustical Society of America,* Vol. 101, p. 3016, 1997.

Smith, K.B., Chiu, C.-S., Miller, J.H., Lynch, J.F., and Gawarkiewicz, G.G., "Three-Dimensional Propagation Effects near the Mid-Atlantic Bight," *Journal of the Acoustical Society of America*, Vol. 102, p. 3143, 1997.

Smith, K.B., "Three-Dimensional Effects on Broadband Pulse Propagation Near Shelfbreaks," *Proceedings of International Conference on Shallow Water Acoustics,* Beijing, China, 21-25 April 1997, in press.

CONFERENCE PRESENTATIONS:

Chiu, C.-S., Smith, K.B., Lynch, J.F., Gawarkiewicz, G.G., Pickart, R.S., Sperry, B., Miller, J.H., and Robinson, A.R., "Measurement and Analysis of the Propagation of Sound from the Continental Slope to the Continental Shelf," Acoustical Society of America, State College, PA, 1997.

Gawarkiewicz, G.G., Pickart, R.S., Lynch, J.F., Chiu, C.-S., Smith, K.B., and Miller, J.H., "The Shelfbreak Front PRIMER Experiment," Acoustical Society of America, State College, PA, 1997.

Smith, K.B., "Three-Dimensional Effects on Broadband Pulse Propagation near Shelfbreaks," International Conference on Shallow Water Acoustics, Beijing, China, 21-25 April 1997.

Smith, K.B., Chiu, C.-S., Miller, J.H., Lynch, J.F., and Gawarkiewicz, G.G., "Three-Dimensional Propagation Effects near the Mid-Atlantic Bight," Acoustical Society of America, State College, PA, 1997.

Smith, K.B. "Analysis of Broadband Propagation in a Highly Variable 3-D Environment Near the Mid-Atlantic Bight," Workshop on Underwater Acoustics, National Taiwan University, Taipei, Taiwan, 10-14 November, 1997.

THESIS DIRECTED:

Sullivan, J., "Analysis of Acoustic Plane-Wave Variability in the Region of the Mid-Atlantic Bight Shelfbreak," Master's Thesis, Naval Postgraduate School, December 1997.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Other (3-D Acoustic Propagation, Littoral Environments)

KEYWORDS: Acoustic Propagation, Azimuthal Coupling, Littoral Environments

EXAMINATION OF 2-D ENVIRONMENTAL MISMATCH AND 3-D ENVIRONMENTAL VARIABILITY INFLUENCES ON LOCALIZATION

Kevin B. Smith, Assistant Professor
Department of Physics
Sponsors: Naval Undersea Warfare Center-Newport Division and Naval Postgraduate School

OBJECTIVE: The scientific objective of this work is to study both the influence of environmental mismatch and propagation mismatch (2-D versus 3-D) on a simple localization algorithm. Synthetic data will also be provided to other investigators testing different algorithms.

SUMMARY: During FY96, research was conducted at the Naval Postgraduate School to determine the robust aspects of acoustic propagation which can be exploited to successfully localize transient phenomena. These results were based on a simple time-domain autocorrelation matching algorithm applied in a simple, range-independent environment. The previous work was expanded and examination was begun on the influences of more realistic environmental variability. Both the influence of environmental mismatch in a 2-D environment and the influence of propagation mismatch in 3-D varying environments were studied. The focus of this study was an examination of the degradation of localization when environmental parameters are varied relative to the "true" environment used to generate the synthetic "measured" data. These variations were based on realistic uncertainties of environmental quantities. This was done in a range-independent manner by simply changing the values or gradients of the water and/or sediment sound speeds, for example, or changing the depth of the water column or thickness of sediment layers. Range-dependent variations were also considered, specifically internal wave variations in the water column sound speed structure. In addition, each of these synthetic results were provided to other investigators to examine similar issues with different localization algorithms. The format of the synthetic data provided was consistent with realistic platform systems and formatted to interface easily with other software.

PUBLICATION:

Smith, K.B., Brune, J., and Chiu, C.-S., "On the Use of Signal Autocorrelation Matching in Localization Algorithms," *Journal of the Acoustical Society of America*, Vol. 102, p. 3192, 1997.

CONFERENCE PRESENTATIONS:

Smith, K.B., Chiu, C.-S., and Brune, J., "Variations of Autocorrelation Matching and Experimental Overview," Working Group Seminar on Passive Transient Localization, Naval Undersea Warfare Center-Newport Division, Newport, RI, 14-15 July 1997.

Smith, K.B., Brune, J., and Chiu, C.-S., "On the Use of Signal Autocorrelation Matching in Localization Algorithms," Acoustical Society of America, State College, PA, 1997.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Sensors, Other (Localization)

KEYWORDS: Parabolic Equation Model, Autocorrelation Matching, Matched Field Processing, Transient Localization

BASIC RESEARCH IN BURSTING BUBBLES AND AEROSOL SOURCE FUNCTIONS

Donald E. Spiel, Research Associate Professor
Department of Physics
Sponsor: Office of Naval Research

OBJECTIVE: The objective of this continuing research is to determine the parameters of bursting ocean bubbles relevant to air-sea interaction and the marine boundary layer. Included are the number, size, and ejection parameters of both jet and film droplets.

SUMMARY: Work on the ejection parameters of jet drops for the bubble size range 0.5 to 3 mm-diameter was completed during 1997. During this year, a hypothesis was advanced to explain the peak in film drop production in the bubble size range 2 to 2.5 mm-diameter was advanced. Measurements of film drop production and theoretical calculations have led to a broad understanding on film drop production.

PUBLICATIONS:

Spiel, D.E., "A Hypothesis Concerning the Peak in Film Drop Production as a Function of Bubble Size," *Journal of Geophysical Research,* 102, 1153-1161, 1997.

Spiel, D.E., "More on the Births of Jet Drops from Bubbles Bursting on Seawater Surfaces," *Journal of Geophysical Research,* 102, 5815-5821, 1997.

DOD KEY TECHNOLOGY AREA: Other (Environmental Effects)

KEYWORDS: Air-Sea Interaction, Jet Drops, Film Drops, Aerosols, Gas Exchange

ATMOSPHERIC OPTICAL TURBULENCE MEASUREMENTS

Donald L. Walters, Associate Professor
Department of Physics
Sponsor: U.S. Air Force Space and Missile Command-Phillips Laboratory

OBJECTIVE: To provide atmospheric optical measurements and consultation for programs of national interest.

SUMMARY: As an active member of U.S. government atmospheric working group team, reviewed government and civilian contractor programs of national interest in over one dozen meetings in Washington DC, Los Angeles, CA, and Albuquerque, NM.

DoD KEY TECHNOLOGY AREA: Other (Adaptive Optical Systems, Imaging Systems)

KEYWORDS: Battlespace Environments, Adaptive Optics, Atmospheric Turbulence

ATMOSPHERIC OPTICAL TURBULENCE MEASUREMENTS FOR THE U.S. AIR FORCE AIRBORNE LASER PROGRAM

Donald L. Walters, Associate Professor
Department of Physics
Sponsor: U.S. Air Force Space and Missile Command-Phillips Laboratory

OBJECTIVE: To participate in the Atmospheric Optical Working Group for the USAF Airborne Laser Program, and to assess and provide stratospheric, atmospheric, thermal-turbulence measurements.

SUMMARY: A reassessment of the microthermal probes uses by the USAF Airborne Laser Program during the last decade, showed how solar illumination introduced a factor-of-ten error in daytime balloon measurements and how the problem could be eliminated.

PUBLICATION:

Walters, D.L. and Richardson, D.J., "Solar Heating Effects on Balloon-Borne Microthermal Probes for the Airborne Laser Program," Naval Postgraduate School Technical Report, NPS-PH-97-006, August 1997.

CONFERENCE PRESENTATION:

Walters, D.L. and Richardson, D.J., "Modeling and Measurements for the ABL Program," Electro-magnetic and Electro-Optical Conference, Monterey, CA, 2-6 June 1997.

THESIS DIRECTED:

Richardson, D.J., "Solar Heating Effects on Balloon-Borne Microthermal Probes for the Airborne Laser Program," Master's Thesis, Naval Postgraduate School, June 1997.

DoD KEY TECHNOLOGY AREA: Battlespace Environments

KEYWORDS: Airborne Laser Program, Microthermal Probes

MESOSCALE MODELING FOR ATMOSPHERIC TURBULENCE, PHASE I

Donald L. Walters, Associate Professor
Department of Physics
Sponsor: Washington, DC

OBJECTIVE: To assess the state in the art of large mesoscale weather models for computing nowcasts and forecasts of atmospheric optical turbulence for programs of national interest.

SUMMARY: To evaluate and assess large weather models such as the COAMPS and MM5 Mesoscale Weather models to predict atmospheric turbulence and cloud formation. Post-processed model results are being compared with existing atmospheric optical data and to assessing the desirability and direction for further work.

DoD KEY TECHNOLOGY AREA: Other (Adaptive Optical Systems, Imaging Systems)

KEYWORDS: Battlespace Environments, Mesoscale Models

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FUSION NEUTRON DAMAGE TO A CHARGE COUPLED DEVICE CAMERA

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A charge coupled device (CCD) camera's performance has been degraded by damage produced by 14 MeV neutrons (n) from the Rotating Target Neutron Source. High-energy neutrons produce atomic dislocation in doped silicon electronics. This thesis explores changes in Dark Current (J), Charge Transfer Inefficiency (CTI), and Contrast Transfer Function (CTF) as measures of neutron damage.

The camera was irradiated to a fluence, f, of 6.60×10^{12} n/cm^2. The camera temperature was lowered from room temperature to 267 K at a fluence of 4.7×10^{11} n/cm^2 to preclude saturation of the camera picture. With temperature compensations, J increased linearly with f. Four data points for J, CTF (ideal of 1.0) and CTI (ideal of 0) are:

Fluence (n/cm^2)	0	4.7×10^{11}	4.7×10^{11}	6.60×10^{12}
Temp (K)	292.1	296.1	276	266.8
J (nAcm^2	0.37	11	0.93	9.8
CTF	0.89	0.37	0.82	0.48
CTI	1.3×10^{-4}	1.2×10^{-3}	2.4×10^{-4}	1.6×10^{-3}

Neutron irradiation significantly degraded CCD camera performance; however, operating the camera at lower temperatures significantly reduces the effects. Damage thresholds for fluences greater than 6.60×10^{12} n/cm^2 and for all temperatures can be extrapolated from this work.

THE UTILITY OF HYPERSPECTRAL DATA TO DETECT AND DISCRIMINATE ACTUAL AND DECOY TARGET VEHICLES

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The objective of this work is to evaluate the utility of hyperspectral signature data in satisfying time-sensitive intelligence requirements. This work is conducted in support of the Hyperspectral MASINT Support to Military Operations (HYMSMO) program. Data are used from the Hyperspectral Digital Imaging Collection Experiment (HYDICE) imaging spectrometer using the 0.4 mm to 2.5 mm wavelength range. Operation Forest Radiance I was the third in a series of HYMSMO-sponsored collection and exploitation experiments, and the data set analyzed herein was derived from this effort. The first phase of the Forest Radiance experiment emphasized the collection of spectra from a suite of overtly exposed mobile vehicles, decoys, and target panels. Analysis shown here was conducted to determine if it is possible to detect and discriminate real and decoy vehicles. The Low Probability of Detection (LPD) and Spectral Angle Mapper (SAM) anomaly detection and classification algorithms are applied to the data set being analyzed. The LPD algorithm performs well at detecting residual spectra, but produces a significant number of false alarms. The SAM technique is equally successful at detecting residual spectra and proves to have an advantage over the LPD when it comes to obviating misidentifications. This thesis shows that detection and discrimination of mobile vehicles (HMMWVs) and decoys in a natural grass environment is possible using this technology.

LINE BROADENING ANALYSIS OF MPD THRUSTERS

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Spectroscopic analysis of the cathode jet of a model coaxial magneto-plasma dynamic (MPD) thruster is conducted to determine electron density and temperature downstream from the cathode. H_b line profiles were scanned from an argon-hydrogen plasma generated in the cathode test facility of the NASA Jet Propulsion Laboratory in Pasadena, CA. A computer program was written in DL to determine the profile Doppler- and Stark half widths, which were used to determine temperature and electron density, respectively. Three sets of data from the cathode test facility were taken, while varying operating voltage, current, hydrogen/argon ratio, and pressure. Radial profiles for electron density and temperature were determined within the cathode jet. Generated plasmas ranged in electron density and temperature from approximately $N_e = 2x10^{14}$ cm^{-3} at 5000 K (0.43 eV) to $4x10^{14}$ cm^{-3} at 15600 K (1.3 eV). It was determined that radial density and temperature distribution within the cathode jet are essentially uniform.

BORO-SILICATE POLYCAPILLARY LENS FOR COLLIMATION OF X-RAYS

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The purpose of this thesis is to investigate the collimation of x-rays produced by transition radiation using the Naval Postgraduate School (NPS) Electron Linear Accelerator. These measurements support the theory that x-rays can be focused using a boro-silicate array of polycapillaries consisting of 258 bundles with 1387 micro-channels each. A 90 MeV electron beam incident upon a non-resonant mylar stack formed transition radiation spatially distributed in an annular cone. The electron beam was deflected 30 degrees using a rare earth permanent magnet. The diverging x-rays incident upon the lens array were transported through total external reflection and directed out of the array onto a phosphor screen. A digital camera recorded the phosphorescing image of the screen. Pixel intensity was analyzed to determine x-ray intensity as a function of two dimensional spatial distribution.

Column average profiles of the pixel intensity show that the transition radiation intensity retains its Gaussian distribution after being redirected from a diverging beam into a mostly parallel beam. The intensity of the x-rays decreased by a factor of 0.72 due to the obstructed area at the face of the array and to imperfect admittance of the diverging x-ray cone into the polycapillary array.

SIMULATION OF THE DYNAMIC BEHAVIOR OF EXPLOSION GAS BUBBLES IN A COMPRESSIBLE FLUID MEDIUM

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Data from one-dimensional (spherically symmetric) analyses was used to examine the effects of compressibility and gas energy on the dynamic behavior of an explosion gas bubble, by comparing the bubble's behavior with experimental results and with analytical results which neglect these factors. Results from two-dimensional (axially symmetric) analyses were used to investigate the behavior of a deep explosion gas bubble in the vicinity of plane rigid or constant pressure boundaries. Previous analytical research into explosion gas bubbles near such boundaries has primarily led to results of a qualitative nature, owing to a complete breakdown of the assumptions made in the analysis at the critical juncture. In the present investigation, it was found possible to characterize the effect of the boundary surface on both the change in the first oscillation period of the bubble and its location at the end of the first oscillation cycle. For a broad range of bubble-boundary standoff distances, these semi-empirical characterizations have a functional form particularly suitable for extension of the quantitative results of this investigation to other explosive charge types, weights, and depths, as has been done for the Willis formula for the free-field oscillation period of explosion gas bubbles.

INVESTIGATION OF A CONSTRICTED ANNULAR ACOUSTIC RESONATOR

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One topic of current interest in thermoacoustic research is an annular prime mover (LIN et al., *Journal of Acoustical Society of America*, 100, 2846, 1996). The starting point for this research is an investigation of a constricted annular resonator. A literature search of the field resulted in surprisingly few references. The results of analytic, numerical, and experimental investigations are presented. Introducing a constriction into an annular resonator splits each longitudinal duct mode into two modes, one of a higher frequency with a pressure antinode at the constriction and one at a lower frequency with a velocity antinode near the constriction. The lower mode is more sensitive to changes in the length and porosity of the constriction than the higher mode. Overall agreement between measured and predicted mode shapes and resonance frequencies is very good. It was found that it is necessary to include end corrections at the constriction to get accurate agreement between measured and predicted results.

NUMERICAL SIMULATION OF BLOCH OSCILLATIONS IN PERIODIC STRUCTURES

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Felix Bloch's 1928 article made a prediction concerning the dynamical behavior of electrons in a solid, subject to a uniform, static electric field. This aspect of his work, as later clarified by Zener, showed that electrons accelerated by an electric field in a periodic potential, under the right conditions, would oscillate. A theoretical debate as to the existence of this phenomenon has been ongoing since Bloch's proposal. One of the most controversial consequences of this prediction is that an electron undergoing Bloch oscillations would radiate. The controversy on the theoretical analysis was due to the great difficulty in systematically and reliably treating interband transitions by analytical methods based on the time-dependent Schrodinger equation is numerically solved for independent electrons. In this thesis, the time-dependent Schrodinger equation is numerically solved to show that electrons accelerated by an electric field in periodic structures do undergo Bloch oscillations and other dynamic behavior. By accurately modeling this phenomenon a better understanding of it will be gained in hopes of using it in future applications as a stable source of Terahertz (THz) radiation.

NON-ELECTRO-OPTIC METHODS OF HIGH FREQUENCY LASER MODULATION

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Two high frequency, non-electro-optic methods for modulating the intensity of a laser are examined theoretically and experimentally. The first modulation technique makes use of the Zeeman effect. Under an applied DC magnetic field, a splitting into two lines or three lines occurs. Modulation rates of 200 MHz have been proven possible with this technique. In the second technique, the properties of self-phase modulation of a monochromatic light are explored. For a high intensity beam, the optical path of a beam can be altered due the dependence of the phase on intensity. Thus two coherent beams of light of different intensity can be made to constructively or destructively interfere even if the physical paths are identical. In a configuration called a nonlinear-optical loop mirror, the output beam is amplitude modulated by linear variations in time of the total input power. A new design for a variable X-coupler, a key element of the loop mirror, is presented. Applications of high frequency modulators to test a theory of the AM-FM conversion of monochromatic light in fibers, to improve pulse rate control during target acquisition, and to high speed communications are discussed.

CONSTRUCTION OF A CONTINUOUS WAVE FREQUENCY MODULATION SENSITIVE LASER RADAR FOR USE IN TARGET IDENTIFICATION

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This thesis covers the theory, design and construction of a continuous wave (CW) frequency modulation sensitive laser radar. Using a commercially available CO_2 laser, optics and electronics, a CW frequency modulation sensitive laser radar was constructed and tested under laboratory conditions. The theory of each component in the laser radar is covered as well as the configuration and design of the radar. Design of a target that enabled measurement of the laser radar's capabilities was also completed. The laser radar was able to accurately measure a target's vibrational frequency and amplitude for

amplitudes greater than 40 nm. The theoretical range of the designed laser radar is over 6 km. An improved optical design that allows a theoretical range of over 9 km is also presented. Applications of target identification are discussed.

NAVAL INFRARED IMAGERY EXPLOITATION (U)

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Infrared Remote sensors often detect thermal excess energy emanating from naval ships through the discharge of seawater used to cool the equipment in the engineering spaces. Once the thermal energy has been detected, the properties associated with the production of that thermal energy could be simulated using a three-dimensional hydrodynamic model. The parameters of the engineering plant are estimated when the simulated thermal plume provides a good representation to the observed energy discharged into the harbor. The synergy of data obtained remotely combined with hydrodynamic modeling can provide insight to the intentions of the vessels.

VARIATIONS ON AUTOCORRELATION MATCHING AND THE SIFT LOCALIZATION ALGORITHM

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As part of the existing acoustic transient localization program, a feasibility study was performed to apply existing algorithms to signals at higher carrier frequencies. The coherent matching, autocorrelation matching and SIFT algorithms are time domain Matched Field Processing algorithms based on arrival structures for single hydrophone applications. In previous studies, these algorithms were employed only at lower frequencies using ray propagation models to create the replicas with varying success. This study is meant to investigate the performance of the algorithms at higher frequencies, using both the University of Miami Parabolic Equation (UMPE) Model and the Hamiltonian Raytracing Program for the Ocean (HARPO), to give insight into the previously unexplained inconsistent behavior of the algorithms at low frequencies, to improve and optimize existing algorithms, to point out improvements to existing eigenray extraction programs, and to suggest additional signal processing on the signal. Simulations are performed and synthetic signals are generated using both the HARPO and UMPE models. The arrival structures are investigated and the relation between features in the arrival structures for matching and the physical parameters are identified. Some insight into the performance of the SIFT algorithm is gained which relates matching and physical parameters. Simulations lead to improvements and optimization of the algorithms and give insight into the performance at higher frequencies.

DESIGN, CONSTRUCTION AND INSTRUMENTATION OF A THERMOACOUSTIC PRIME MOVER WITHOUT A STACK

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This thesis is written to document the design, construction and instrumentation of a thermoacoustic prime mover without a stack. A thermoacoustic prime mover uses a temperature differential maintained between two heat exchangers to produce sound, i.e., work in a resonator. The no stack design may offer improved efficiencies over current designs which use a stack

by eliminating the thermal and viscous losses associated with the stack. A detailed description of the construction of the experimental components and the instrumentation is provided.

AN ANALYSIS OF THE IIR AND FIR WIENER FILTERS WITH APPLICATIONS TO UNDERWATER ACOUSTICS

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A detailed analysis of the performance the Wiener optimal filter for estimating a signal in additive noise is carried out. A first order AR model is assumed for both the signal and noise. Both IIR and FIR forms of the filter are considered and expressions are derived for the processing gain, mean-square error, and signal distortion. These measures are plotted as a function of the model parameters. This analysis motivates a generalized form of the Wiener filter, which can improve the signal distortion. An analysis of this more general filter is then carried out. A practical noise removal algorithm based on short-time filtering using the generalized filter is also described and results of applying the algorithm to some typical underwater acoustic data are presented.

COMPUTER PROGRAMS SUPPORTING INSTRUCTION IN ACOUSTICS

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Traditionally, the study of mechanical vibration and sound wave propagation has been presented through textbooks, classroom discussion and laboratory experiments. However, in today's academic environment, students have access to high performance computing facilities which can greatly augment the learning process. This thesis provides computer algorithms for examining selected topics drawn from the text, *Fundamentals of Acoustics*, Third Edition, John Wiley & Sons, Inc., by Kinsler, Frey, Coppens, and Sanders, (KFCS). Emphasis is on using the modeling and simulation capability of the programming language, MATLAB, to illustrate and analyze complex physical principles which may seem obscure on the printed page yet are challenging or inconvenient to duplicate in the laboratory. This is not a passive recitation of acoustic phenomena, but complements KFCS with interactive student participation. The usefulness of these programs and any weaknesses in format or content needs to be tested in the classroom.

A SIMULATION OF THE LUNAR PROSPECTOR'S GAMMA RAY SPECTROMETER

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The expected response of the Lunar Prospector's Gamma Ray Spectrometer instrument was predicted using a Monte Carlo simulation. The full lunar spectrum was generated using 90 lines and a continuum gamma ray background taken from Apollo 15 and 16 data. The Monte Carlo program uses the exact dimensions and composition of the Gamma Ray Spectrometer in order to most accurately predict spectral performance, assuming an operating temperature on orbit of-30 0C. The

Gamma Ray Spectrometer will be launched aboard the Lunar Prospector spacecraft on October 24, 1997. The Lunar Prospector will assume a 100 km altitude orbit around the moon, allowing the Gamma Ray Spectrometer to map the elemental composition of the surface. The simulated Gamma Ray Spectrometer response can be used as a comparison for the actual data in order to determine how well the spectrometer is working.

INSTRUMENTATION AND MEASUREMENT OF A THERMOACOUSTICALLY DRIVEN THERMOACOUSTIC REFRIGERATOR

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This thesis is written to document the design, instrumentation and initial operation of a thermoacoustically driven thermoacoustic refrigerator. This design combines a quarter wavelength acoustic motor and a quarter wavelength acoustic refrigerator in a common resonator. Electrically generated heat provides power to the acoustic motor, producing a standing pressure wave, which is used by the refrigerator to produce cooling power. Several techniques are employed in the design to increase the efficiency of both the driver and the refrigerator compared to previous designs. A detailed description of the design and calibration of the required measurement instrumentation is provided. Finally, some initial driver data is presented.

ACOUSTIC CASIMIR EFFECT

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In 1948, Hendrick Brugt Gerhard Casimir predicted that two closely spaced uncharged conducting plates in vacuum would be mutually attracted. This attractive force is an indirect manifestation of the quantum electromagnetic zero point field (ZPF). When the indirect manifestations of the ZPF are interpreted as due to radiation pressure, acoustic noise can provide an excellent analog to investigate the Casimir effect as well as other effects due to the ZPF. Force measurements between two parallel plates are performed in an acoustic chamber with a broadband noise spectrum within a 5-15 kHz band and an intensity of 133 dB (re 20 mPa). When the results are compared with the appropriate theory, very good agreement is obtained. Applications of the acoustic Casimir effect to noise transduction can provide new means to measure background noise. Because attractive or repulsive forces can be obtained by adjusting the noise spectrum or the plate geometry, a non-resonant method of acoustic levitation is also suggested.

NUMERICAL SIMULATIONS OF SHOCKLESS NONLINEAR ACOUSTICS NOISE IN ONE DIMENSION

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The attenuation of a monochromatic signal in the presence of discrete noise in one dimension is investigated numerically. The predicted Gaussian attenuation is verified by the numerical program, which is based on Riemann's implicit solution of the exact equation for the unidirectional propagation of shockless sound. Two new results are also presented. In the first, the transition from Gaussian to Bessel dependence as a function of resolution in the detection of a signal is observed. This results shows that the fundamental property of time reversibility can only be established if the overall system of the waves and the observer is considered. In the second result, the evolution of the amplitude of a signal injected downstream from the noise is investigated. The Gaussian attenuation is also observed in this case. This result explicitly shows that the attenuation length depends on the distance the signal has traveled, thus displaying memory and breakdown of translational invariance.

DESIGN, DEVELOPMENT, AND TESTING OF AN ULTRAVIOLET HYPERSPECTRAL IMAGER

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This research involved the development of an ultraviolet (UV) hyperspectral imager. A hyperspectral image is a three dimensional image in which two of the dimensions provide spatial information and the third provides spectral information. In an effort to minimize the cost of this experiment, the NPS Middle Ultraviolet SpecTrograph for Analysis of Nitrogen Gases (MUSTANG) instrument was modified to function as a hyperspectral imager. This required the design, fabrication, and testing of hardware and software to coordinate the operation of a two dimensional, charge coupled device (CCD) detector with a servo-controlled scanning mirror. Control and synchronization of scanning mirror and image collection was accomplished by software (written in Borland C++) run from an Intel microprocessor based PC. The benefits of a UV hyperspectral imager are primarily in the area of Support to Military Operations (SMO). There are two principal applications: 1) target identification, and 2) battle damage assessment. Additionally, this instrument has dual use applications, namely, 1) redirection of jet aircraft to avoid the foreign object damage (FOD) hazards presented by volcanic ash clouds through analysis of the absorption of solar UV radiation by the sulfur dioxide (SO_2) gas associated with volcanic ash, and 2) forest fire detection.

ROBOT WARS SIMULATION

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Naval Postgraduate School (NPS) Combat Systems students learn about robots and autonomous weapons during group design projects in the SE 3015 course sequence. This sequence is designed to provide experience in combat systems development. The capstone project is the Robot Wars Competition, where pairs of student-designed autonomous robots battle each other. This thesis extends this competition into the arena of simulation and modeling. Our motivation is to further

students' understanding of the strengths and weaknesses of computer modeling and simulation in combat systems design and testing.

This thesis creates a simulation foundation of the Robot Wars Competition. The simulation has been designed in two main parts, a C++ program that manipulates the Simbots on the playing field and generates data files of their movements, and a 3D graphical visualization that allows the user to see the Simbots in action. The C++ program uses a Simbot class to instantiate two Simbots which are composed of three basic components: base, optics and weapons. The graphics portion uses data files created in the main simulation and displays in 3D animation. The simulation correctly replicates the logical and physical aspects of the robot competition. Future research on the physical aspects of the component parts and the graphics package can be integrated with this foundation.

THE USE OF NON-PARAMETRIC TRANSFER FUNCTION ESTIMATES TO PREDICT SUBMARINE HULL VIBRATIONS FROM NOISE SOURCE MEASUREMENTS (U)

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Fundamental and practical limitations in the ability of non-parametric transfer function estimates to predict submarine hull vibrations are investigated. In order to assess the prediction performance and to succeed with non-stationary transfer functions, new methods and terminology are developed. An expression is derived for the maximum fractional error due to leakage which can be expected for the prediction of a pure sinusoid. For the data analysis, Bendat and Piersol's techniques for multiple-correlated inputs are used to condition up to eight input signals. Data is analyzed in three stages of complexity. The first data analyzed is from a scale model submarine driven by shakers. The next data is from the *USS Dolphin*, a deep-diving diesel-electric submarine. Measurements were taken on the Dolphin both surfaced running on diesels and submerged running on battery. During the submerged runs a minimal engineering line-up was used to limit the number of active noise sources. The final data analyzed was obtained from the *USS Hartford*, a nuclear attack submarine while in a normal engineering line-up. Results discussed include the percentage of power remaining in the processed hull signals, the lack of sensitivity of the predictions to input order, and the practical limitations encountered.

MODELING THE QUANTUM DOT

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Much of the progress in solid-state microelectronics has come from the continued reduction in size of the transistors that make up integrated circuits (ICs), having dropped by a factor of 10 in the last decade to where minimum device geometries have reached approximately 350 nanometers in mass production. Continued improvements in ICs will require a device technology that can be scaled down to the sub-100 nanometer size regime. There, the quantum mechanical nature of the electron becomes strongly evident, and new design tools are required for a nano-electronic semiconductor technology. The combined scaling and speed advantages of these new devices could portend orders of magnitude increases in the functional performance of future-generation ICs.

Quantum device performance is extremely sensitive to small variations in design parameters. Accurate theoretical modeling is therefore required to guide the technology development. Conventional device design tools are based on classical physics, and do not incorporate quantum effects. New design tools are required to explicitly account for the quantum effects that control charge transport at the nanometer scale. To further understand and develop nanoscale device technology, this thesis will model the potential energy function in a quantum dot, a nanostructure in which electrons are quantum-mechanically confined in all three dimensions and which represents the inevitable result of continued downscaling of semiconductor devices.

EXPERIMENTAL AND NUMERICAL INVESTIGATIONS OF THE GAUSSIAN SUPPRESSION OF SOUND BY SOUND

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In this work we report on experimental and numerical investigations of the attenuation of a small-amplitude signal due to its interaction with high intensity, band limited sound whose spectrum consists of up to four discrete peaks. We probe the "thermodynamic limit" for different configurations of the spectral components. In particular the attenuation of the signal is investigated for both equally and unequally spaced spectral components, as well as different phase relations among them. The possibility of collective modes is also explored by measurements of the phase change in the signal downstream due to the presence of discrete noise.

HARDWARE MODIFICATIONS AND INSTRUMENTATION OF THE THERMOACOUSTICALLY DRIVEN THERMOACOUSTIC REFRIGERATOR

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This thesis describes hardware modifications, instrumentation, and measurements taken with a heat driven refrigerator apparatus. Basic engine operation requires a heat source for the thermoacoustic driver which produces a high amplitude acoustic standing wave in a resonant vessel. Acoustic energy is extracted from the wave by the thermoacoustic refrigerator, located in the same vessel, which produces the cooling power. The engine has no moving parts.

The measurements characterize the performance of the driver half of the engine in terms of amplitude and heat input with respect to changes of the "stack" component, resonator tuning, and gas type. Amplitudes as high as 9.5% (peak/mean pressure) were achieved, and control of onset and amplitude were generally excellent although some amplitude instabilities were observed. Preliminary refrigeration measurements were also made, with substantial amounts of cooling power produced.

AN ANNULAR THERMOACOUSTIC PRIME MOVER

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The dissertation constitutes the first detailed theoretical and experimental investigation of a thermoacoustic prime mover with periodic boundary conditions. There are five significant aspects to this research: (1) using DeltaE to analyze an annular prime mover, (2) developing an entirely new analysis program using MATLAB, (3) designing, building, and experimentally investigating a single stack, annular prime mover, (4) experimentally investigating a constricted, single stack prime mover, and (5) predicting the performance of a two stack annular prime mover. The major conclusions are: (1) A single stack annular prime mover will not reach onset because the eigenmodes of the system do not support thermoacoustic growth, (2) A constricted annular prime mover will reach onset because the constriction forces dominating boundary conditions that alter the eigenmodes, and (3) A two stack prime mover is predicted to reach onset because one of the eigenmodes of the symmetric system does support thermoacoustics.

THE DESIGN OF THE NAVAL POSTGRADUATE SCHOOL'S ULTRAVIOLET IMAGING SPECTROMETER (NUVIS)

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Hyperspectral imaging spectrometers are remote sensing instruments capable of producing an image cube comprised of a two-dimensional scene and the corresponding spectra of each scene element remote sensing is growing in civilian applications and support of military operations. Civilian applications vary from plant species identification, stress measurement, leaf water content and canopy chemistry to geological identification and mapping. Military applications include target identification and classification, bomb damage assessment, terrain or area utilization and rocket plume identification.

This thesis describes the fabrication and alignment of the NPS Ultraviolet Imaging Spectrometer (NUVIS). NUVIS is a hyperspectral imaging spectrometer designed to investigate the added value of the ultraviolet region of the spectrum. The spectrometer is comprised of a telescope assembly using an off-axis parabolic mirror, a slit, a flat-field imaging diffraction grating and a camera assembly. This is the first part of a continuing project to build, test and use this sensor for support of military operations.

OCEAN WAVE DATA ANALYSIS USING HILBERT TRANSFORM TECHNIQUES

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A novel technique to determine the phase velocity of long-wavelength shoaling waves is investigated. Operationally, the technique consists of three steps. First, using the Hilbert transform of a time series, the phase of the analytic signal is

determined. Second, the correlations of the phases of analytic signals between two points in space are calculated and an average time of travel of the wave fronts is obtained. Third, if directional spectra are available or can be determined from time series of large array of buoys, the angular information can be used to determine the true time of travel. The phase velocity is obtained by dividing the distance between buoys by the correlation time. Using the Hilbert transform approach, there is no explicit assumption of the relation between frequency and wavenumber of waves in the wave field, indicating that it may be applicable to arbitrary wave fields, both linear and nonlinear. Limitations of the approach are discussed.

A SIMULATION STUDY OF ACOUSTIC VARIABILITY DUE TO INTERNAL SOLITARY WAVES ON THE MID-ATLANTIC CONTINENTAL SHELF

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During the summer of 1995, a multi-institutional field study called Shallow-Water Acoustic Random Medium (SWARM) was conducted in the Mid-Atlantic Bight continental shelf region off the coast of New Jersey. Environmental and acoustic sensors were deployed as part of SWARM to measure and characterize the internal waves and their impact on the spatial and temporal coherence of the acoustic transmissions. As part of the environmental monitoring network, two bottom-moored, upward-looking acoustic Doppler current profilers (ADCPs) were deployed. Large-amplitude, non-linear, internal soliton wave packets were observed to propagate shoreward from the shelfbreak. Based on the ADCP observations, a kinematic model of the soliton wave packets was developed to synthesize the corresponding temporal and spatial fluctuations in the sound-speed field. Using a coupled normal-mode sound propagation model and the synthesized sound speed variations, the variability of sound pressure and of the modal amplitudes for a 224 Hz CW transmission were simulated. The auto and cross-correlations of sound pressure at different depths, and of the modal amplitudes at a fixed range, were computed in an effort to estimate the vertical and temporal scales of the fluctuating sound field. The simulation method, the simulated acoustic variability as well as the results of the correlation analysis are presented and discussed in this report.

ANALYSIS OF HYPERSPECTRAL DATA USING POLARIMETRIC CHARACTERISTICS

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The utility of polarimetric reflectance characteristics of targets and background surfaces in the analysis of hyperspectral imagery data is investigated. A technique is proposed for filtering a data hypercube of an imaged scene to select targets for subsequent analysis using standard hyperspectral signature matching techniques, thereby reducing image analysis time. An experimental study to measure polarization characteristics of reflected light from various surfaces in order to determine wavelengths for maximum and minimum intensity differences between polarized reflectance values is proposed. A second study is outlined for collection of simulated hyperspectral imagery that would attempt to validate the proposed filtering technique. A research of past studies indicate that useful polarization signature components are present for many targets and target materials. Additionally, backgrounds composed of grass, trees, dirt, and clouds generate very little polarized components making detection of targets using polarization signatures feasible.

SOLAR HEATING EFFECTS ON BALLOON-BORNE MICROTHERMAL PROBES FOR THE AIRBORNE LASER PROGRAM

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Atmospheric optical turbulence induces phase fluctuations in a propagating electromagnetic wave. The resulting degradation in coherence limits the capability of any laser, target acquisition, or surveillance system. Past data collection methods for the parameterization of atmospheric turbulence profiles, in support of critical Theater Ballistic Missile Defense (TBM) systems, from ground level to 30 km, have depended on meteorological balloon-thermosonde systems, probes carried on the U.S. Air Force Argus aircraft, as well as radar and optical measurements. The balloon and aircraft systems measure temperature fluctuations and compute the temperature structure function, C_T^2 and the related index of refraction structure parameter, C_n^2. It has recently become critical to explain why turbulence profiles from daytime thermosonde data consistently show a two order of magnitude increase over that taken during the night, primarily between 12-20 km.

This thesis analyzed the TSI 3.8 μm platinum coated tungsten thermosonde probe used by the USAF Research Laboratory (AFRL) to quantify the magnitude of the solar heating and to investigate other heat transfer mechanisms in the probe. A model of the thin wire probe was developed to identify each of the contributions to the temperature error and its significance. Experimental measurements where collected to verify most aspects of the final model.

We found that the sun induces a temperature rise in the TSI 3.8 μm fine wire probe, during the day, that can vary from near zero to 0.175 K. It is strongly dependent on probe orientation with respect to the sun and on variations in the air flow over the probe. This then causes an apparent increase by two orders of magnitude in the daytime measurements of the optical turbulence parameters C_T^2 and C_n^2.

FREE ELECTRON LASER WEAPONS AND ELECTRON BEAM TRANSPORT

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The Navy is exploring the possibility of using a MW class free electron laser (FEL) as a ship self-defense weapon against anti-ship missiles. The Navy has helped fund the construction of a KW average power FEL and has held workshops to discuss weapons class FELs.

A design workshop resulted in two possible MW FELs which are examined. One of these designs, the MW regenerative amplifier FEL, is looked at further to determine the feasibility of its design parameters. The second design, the MW oscillator FEL, presents a challenge in understanding the electron beam transport phenomena known as coherent synchrotron radiation (CSR). A workshop concluded that CSR is potentially disruptive in the electron beam recovery in the oscillator design. Possible CSR experiments are analyzed to help the Navy's Directed Energy office determine which, if any, CSR experiment will be useful.

ACOUSTIC SOURCE AND DATA ACQUISITION SYSTEM FOR A HELICOPTER ROTOR BLADE-VORTEX INTERACTION (BVI) NOISE REDUCTION EXPERIMENT

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One of the most objectional noises produced by a helicopter is due to interaction of a rotor blade with a previously shed vortex. Various methods have been proposed to reduce this blade-vortex interaction (BVI) noise; this investigation is concerned with BVI noise reduction by rotor blade tip design modifications. Potentially much can be learned regarding the prospect for success of a candidate rotor blade design at greatly reduced time and money by performing acoustic scattering measurements in an anechoic chamber. It is proposed that a rotor blade which scatters acoustic waves less could be expected to produce less BVI noise. This thesis describes the development of the acoustic source and computer controlled data acquisition system for such a scattering experiment.

HIGH-ACCURACY DISTRIBUTED SENSOR TIME-SPACE-POSITION INFORMATION SYSTEM FOR CAPTIVE-CARRY FIELD EXPERIMENTS

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Operational EW test and evaluation experiments require that the position of the aircraft and other moving objects on the range be known precisely as a function of time. Terminal Time-Space-Position Information (TSPI) Systems involve the range platforms interacting at close distances and therefore require precise trajectory information over a restricted volume of space. Terminal TPSI systems are used for tactics evaluation and the evaluation of simulated weapons firings (e.g., captive-carry hardware-in-the loop missile simulators). Distributed sensor TSPI systems consist of two or more measurement sensors located some distance from each other. Each sensor makes a measurement of target angle and range. Distributed sensor systems are more complex than single-point systems involving multiple hardware installations, complex mathematical computations to extract coordinate information, synchronization of multiple measurements and calibration of a number of different stations.

This paper presents a novel distributed sensor TSPI architecture that provides precise positioning information of the target relative to a fixed inertial coordinate system. The architecture efficiently integrates the information from an inertial navigation system (INS), a global positioning system (GPS) and any number of distributed RF sensors which may be located onboard a captive-carry aircraft. The significance of this work is that by knowing the target's position in a fixed inertial frame of reference (derived from the integration process) an evaluation can be made as to the effectiveness of any electronic attack or off-board decoys that might have been launched during the field test scenario. The induced INS, GPS and sensor noise and the corresponding errors due to the integration process are evaluated numerically as a function of the weapons system being used. The accuracy in the targeting information is also quantified and compared wiht the true expected values.

EVOLUTION OF THE TEMPERATURE PROFILE IN A SIMPLE THERMOACOUSTIC STACK

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The purpose of this thesis is to provide data on the evolution of the temperature profile in a simple thermoacoustic stack. These measurements are made to support the development of nonlinear time-dependent models of thermoacoustics. An acoustic resonator and driver is used with a five-plate stainless steel stack. The center plate of the stack is instrumented with nine thermocouples, one in the midpoint and four near each end of the plate. The edge thermocouples are located within an acoustic displacement amplitude of one another at high amplitude drive conditions.

Temperature evolution data is recorded for both argon and helium gases at several mean pressures and several drive ratios with the stack located between a pressure node and antinode. This data showed a deviation from linear theory at drive ratios above 1.5%. A crossover of gradient magnitudes is evident during gradient formation with edge thermocouple pairs initially forming larger gradients but dropping in magnitude to less than those of the inner thermocouple pairs after 25-56 seconds. As the gradients approached steady state conditions, they split into two groups of gradient pairs that appeared independent of displacement amplitude. Measurements are also made with the stack positioned in the vicinity of a pressure node and a pressure anti node. This data will be used for future study.

INTERACTION OF LASER BEAMS WITH RELATIVISTIC ELECTRONS

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Motivated by the desire to put a free electron laser (FEL) weapon on a ship, the FEL and the related process of Compton backscattering are studied. The theme of the majority of this work is the interaction of the Gaussian optical mode with a beam of relativistic electrons.

Classical FEL theory is reviewed in Chapter II. Simulations based on the classical theory are used in Chapter III to study a proposed 1 kW (kilowatt) infrared FEL. In Chapter IV, simulation is used to study the problem of electron beam/optical mode overlap in an ultraviolet (UV) FEL. A new concept, the FEL with a short Rayleigh length, is studied in Chapter V. The idea is tested on the UV FEL, then used to design and simulate a megawatt-class FEL for ship self-defense.

An analytical calculation of the Compton backscattering of laser light is performed in Chapter VI. A quantum electrodynamics (QED) formalism is used to find the spectrum and angular distribution of photons scattered out of a Gaussian optical mode by relativistic electrons.

ANALYSIS OF MODAL TRAVEL TIME VARIABILITY DUE TO MESOSCALE OCEAN STRUCTURE

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This dissertation examines the effects of ocean mesoscale variability on acoustic arrival time patterns for two separate ocean environments. First, for an open ocean environment away from strong boundary currents, the effects of randomly phased linear baroclinic Rossby waves on acoustic travel time are shown to produce a variable overall spreading in the arrival pattern, primarily producing a delay in the later, axial arrivals. Second, using the state-of-the-art Semtner-Chervin eddy resolving global ocean circulation model coupled with the University of Miami Parabolic Equation (UMPE) acoustic propagation model, the effects of a fluctuating frontal region created by the California Current on the temporal, spatial and seasonal variability in the individual modal arrivals of the first thirty modes over a one-model-year time span is assessed. The mesoscale bias variability is also examined by comparing the various peak arrival times for the range-averaged environment to that of the range-dependent environment. To support this work, approximate "wide angle PE mode functions" were newly developed which form a different basis set for modal expansion from that obtained using standard normal mode theory. These new mode functions provide the proper basis set for modal expansion of the field computed by wide-angle PE models.

BATHYMETRY FROM HYPERSPECTRAL IMAGERY

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Master of Science in Physics-December 1996
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This work used hyperspectral imagery to derive shallow water depth estimates. A technique to classify substrates and estimate reflectance values for the substrate types is the major contributions of this work. This was accomplished by masking different bottom types based on spectra, effects that were not included in previous methods. HYDICE data was taken over Lake Tahoe on June 22, 1995. The high altitude of the lake provided a low aerosol content within the atmosphere. This allowed for relatively straightforward atmospheric corrections. This was substantially easier than in an oceanic environment. The atmospheric radiative transfer code MODTRAN3.0 was used to model the atmospheric conditions at the time of the experiment. The radiative transfer code HYDROLIGHT3.5 was used to model the attenuation coefficients of the relatively clear water of the lake. Minimal river input and low chlorophyll concentrations made it simpler to determine these values. Making use of the full spectral content of data within the optical range, multiple substrates were differentiated and masked off. This allowed for an estimation on wet substrate reflectance and a straightforward calculation of bottom depth.

CASIMIR ACOUSTICS

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When the indirect manifestations of the electromagnetic ZPF are interpreted as due to radiation pressure, acoustic noise can render an excellent analog to probe previous as well as recently proposed behavior. An acoustic chamber for isotropic and homogeneous acoustic noise of controllable spectral shape has been built. The noise can be driven up to levels of 130dB (re 20 mPa) in a band of frequencies up to 50 kHz wide. When driving the system with broadband noise, it will be used: (i) to test the Galilean invariance of a spectral shape proportional to the square of the frequency, (ii) the force of attraction between parallel plates (analog to Casimir force), (iii) the acoustic radiation emitted by a cavity that is made to oscillate at high frequencies (analog to the proposed Casimir radiation), (iv) the change in the frequency of oscillation of a pendulum as the noise intensity is varied (analog to the proposed origin of inertia), and (v) the force of attraction between two spheres due to the acoustic shadow that each one casts onto the other (analog to van der Waals force and the proposed origin of gravitation).

FRAGMENT IMPACT ON A CHEMICAL WARHEAD (U)

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Current U.S. strategic policy has placed significant emphasis on Theater Missile Defense (TMD); problems associated with high-altitude intercept and destruction of threat missile Systems are extensive. The actual missile-to-missile encounter is anticipated to occur anywhere from exoatmospheric altitudes to very low endoatmospheric altitudes. Conduct of experiments to simulate these conditions at these altitudes is hampered by the inability to produce, at ground level, the velocity and atmospheric conditions associated with actual missile-to-missile encounters. However, experiments have been conducted at a reduced scale, for velocity and atmospheric conditions, for both the interceptor and target.

The objective of this thesis is to evaluate the role target obliquity and hole size have on fragment lethality of TMD interceptors. Also, the ability of the fragment model within the Parametric Endo/Exoatmospheric Lethality Simulation (PEELS) is evaluated for representation of the above parameters. In order to evaluate the significance of obliquity on a fragment intercept and the ability of PEELS to accurately represent that intercept, this thesis will first examine the intercept conditions of two different fragmenting warhead missiles, one directional and one aimable, against a threat chemical payload ballistic missile. Aimable warheads focus the fragment spray directly on the target, thereby increasing the probability of hit and the probability of kill given a hit on the target. Directional warheads have charges placed around the warhead to direct the blast through the timing of the charges, thereby increasing the hit probability. Experiments relevant to the intercept conditions are analyzed to better understand the phenomeno- logy of fragment impact that occurs at these conditions. Next, the current Parametric Endo/Exothermic Lethality Simulation (PEELS) fragmentation methodology, produced by Kaman Sciences Corporation, is compared to the intercept conditions and experimental data. Finally, hole size in the aeroshell, produced by interceptor fragments will be examined to determine if enhanced lethality is obtained for the aimable fragmenting warheads.

HIGH FREQUENCY CHARACTERIZATION OF THE GSANGER LM0202P ELECTRO-OPTIC MODULATOR

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This thesis documents experiments conducted with the Gsanger LM0202P electro-optic modulator to achieve a high percentage modulation at 125MHz of an argon-ion laser. The laser was tuned to produce a single mode, linearly polarized light at 514.5 nm. The laser light was first passed through the electro-optic crystal modulator with no external electric field applied, and the frequency spectrum was observed to be the same as the frequency spectrum of the source laser. When an AC voltage with a frequency of 125 MHz was applied to the modulator sidebands were observed by using a Fabry-Perot interferometer. Further measurements were taken to determine the suitability of the LM0202P modulator over a large frequency range.

ALTERNATIVE PATHWAYS TO NUCLEAR WEAPONS PRODUCTION (U)

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CLASSIFIED ABSTRACT

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